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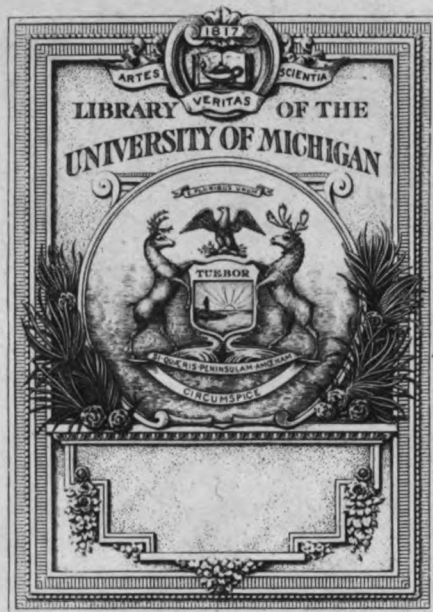
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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY


PUBLISHED QUARTERLY

BOARD OF EDITORS

J. S. AMES

M. I. PUPIN

ERNEST MERRITT

VOLUME I AND II

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PUBLISHED BY
THE AMERICAN PHYSICAL SOCIETY

1900

American Physical Society.

Officers.

HENRY A. ROWLAND,	<i>President</i>
ALBERT A. MICHELSON,	<i>Vice-President</i>
ERNEST MERRITT,	<i>Secretary</i>
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CHAS. I. HASTINGS,	A. G. WEBSTER.

Program Committee and Board of Editors of the Bulletin.

J. S. AMES, M. I. PUPIN, ERNEST MERRITT.

The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

THE AMERICAN PHYSICAL SOCIETY.

Minutes of the First Meeting.

MORNING SESSION.

The first meeting of the Society was held in Room 304 Fayerweather Hall, Columbia University, New York City, on Saturday, May 20, 1899, at 10:30 A. M.

The meeting was welcomed on behalf of the University by Professor M. I. Pupin.

On motion of Professor Pupin, Professor LeRoy C. Cooley was made temporary chairman, and Professor A. G. Webster was elected secretary of the meeting.

On motion it was resolved that a Physical Society be formally organized.

On motion a committee was appointed, consisting of Messrs. A. G. Webster, E. L. Nichols, W. F. Magie, B. O. Peirce, Wm. Hall-ock, and M. I. Pupin, to draft a constitution.

After a general discussion of the aims and policy of the Society it was voted that, except in special cases, the meetings be held in New York City; that the meeting express the willingness of the Society to establish local sub-sections when demand shall arise; and that it further express the sentiment of the Society to cultivate the closest relations with Section B of the American Association for the Advancement of Science, and to contribute by every thing in its power to the latter's success.

AFTERNOON SESSION.

Called to order at 2:20 P. M.

The Committee on Constitution reported a preliminary draft which,

after discussion, was referred to the Council for further revision, with the following instructions: That the election of members be by the Council; that there be four regular meetings annually; that the annual fee be five dollars; and that a regular bulletin be published.

The meeting then proceeded to the election of officers. The following named gentlemen were unanimously elected:

HENRY A. ROWLAND,	-----	<i>President.</i>
ALBERT A. MICHELSON,	-----	<i>Vice President.</i>
ERNEST MERRITT,	-----	<i>Secretary.</i>
WILLIAM HALLOCK,	-----	<i>Treasurer.</i>

The following gentlemen were elected members of the Council:

A. G. WEBSTER,	J. S. AMES,
H. S. CARHART,	B. O. PEIRCE,
W. F. MAGIE,	E. L. NICHOLS,
M. I. PUPIN.	

Adjourned.

Minutes of the Second Meeting.

MORNING SESSION.

Regular meeting, held in Fayerweather Hall, Columbia University, October 28, 1899.

The meeting was opened by the Presidential Address of Professor Henry A. Rowland.

At the close of the Presidential Address, the minutes of the last meeting were read and approved.

The meeting then proceeded to the consideration of the Constitution and By-Laws, recommended by the Council for adoption.

On motion the Constitution and the By-Laws, as modified at the suggestion of the Council, were adopted.

It was moved and carried that the question of the election of foreign and honorary members of the Society be referred to the Council, with directions to report at the next meeting.

On motion it was unanimously resolved that Article I of the By-Laws be suspended for this meeting.

It was moved and carried that the President be excused from giving another address at the annual meeting in December.

Noon recess.

AFTERNOON SESSION.

The meeting was called to order by President Henry A. Rowland.

The following papers were presented :

1. An account of some experiments to determine the properties of the ether. Henry A. Rowland.
2. On the deduction of the equations of electro-magnetic waves. A. G. Webster.
3. On an electrolytic rectifier for alternating currents. M. I. Pupin.
4. On a new apparatus to show the motion of the top. A. G. Webster.

Adjourned.

THE HIGHEST AIM OF THE PHYSICIST.

BY HENRY A. ROWLAND.

[PRESIDENTIAL ADDRESS DELIVERED AT THE SECOND MEETING OF THE SOCIETY, ON OCTOBER 28, 1899.]

Gentlemen and Fellow Physicists of America :

We meet to-day on an occasion which marks an epoch in the history of physics in America ; may the future show that it also marks an epoch in the history of the science which this society is organized to cultivate ! For we meet here in the interest of a science above all sciences, which deals with the foundation of the Universe, with the constitution of matter from which everything in the Universe is made, and with the ether of space by which alone the various portions of matter forming the Universe affect each other even at such distances as we may never expect to traverse whatever the progress of our science in the future.

We, who have devoted our lives to the solution of problems connected with physics, now meet together to help each other and to forward the interests of the subject which we love. A subject which appeals most strongly to the better instincts of our nature, and the problems of which tax our minds to the limit of their capacity and suggest the grandest and noblest ideas of which they are capable.

In a country where the doctrine of the equal rights of man has been distorted to mean the equality of man in other respects, we form a small and unique body of men, a new variety of the human race, as one of our greatest scientists calls it, whose views of what constitutes the greatest achievement in life are very different from those around us. In this respect we form an aristocracy, not of wealth, not of pedigree, but of intellect and of ideals, holding him in the highest respect who adds the most to our knowledge or who strives after it as the highest good.

Thus we meet together for mutual sympathy and the interchange of knowledge, and may we do so ever with appreciation of the benefits to ourselves and possibly to our science. Above all, let us

cultivate the idea of the dignity of our pursuit, so that this feeling may sustain us in the midst of a world which gives its highest praise, not to the investigation in the pure etherial physics which our society is formed to cultivate, but to the one who uses it for satisfying the physical rather than the intellectual needs of mankind. He who makes two blades of grass grow where one grew before is the benefactor of mankind ; but he who obscurely worked to find the laws of such growth is the intellectual superior as well as the greater benefactor of the two.

How stands our country, then, in this respect ? My answer must still be now as it was fifteen years ago, that much of the intellect of the country is still wasted in the pursuit of so-called practical science which ministers to our physical needs and but little thought and money is given to the grander portion of the subject which appeals to our intellect alone. But your presence here gives evidence that such a condition is not to last forever.

Even in the past we have the names of a few whom scientists throughout the world delight to honor. Franklin, who almost revolutionized the science of electricity by a few simple but profound experiments. Count Rumford, whose experiments almost demonstrated the nature of heat. Henry, who might have done much for the progress of physics had he published more fully the results of his investigations. Mayer, whose simple and ingenious experiments have been a source of pleasure and profit to many. This is the meager list of those whom death allows me to speak of and who have earned mention here by doing something for the progress of our science. And yet the record has been searched for more than a hundred years. How different had I started to record those who have made useful and beneficial inventions !

But I know, when I look in the faces of those before me, where the eager intellect and high purpose sit enthroned on bodies possessing the vigor and strength of youth, that the writer of a hundred years hence can no longer throw such a reproach upon our country. Nor can we blame those who have gone before us. The progress of every science shows us the condition of its growth. Very few persons, if isolated in a semi-civilized land, have either the desire or the opportunity of pursuing the higher branches of science. Even if they should be able to do so, their influence on

their science depends upon what they publish and make known to the world. A hermit philosopher we can imagine might make many useful discoveries. Yet, if he keeps them to himself, he can never claim to have benefited the world in any degree. His unpublished results are his private gain, but the world is no better off until he has made them known in language strong enough to call attention to them and to convince the world of their truth. Thus, to encourage the growth of any science, the best thing we can do is to meet together in its interest, to discuss its problems, to criticise each other's work and, best of all, to provide means by which the better portion of it may be made known to the world. Furthermore, let us encourage discrimination in our thoughts and work. Let us recognize the eras when great thoughts have been introduced into our subject and let us honor the great men who introduced and proved them correct. Let us forever reject such foolish ideas as the equality of mankind and carefully give the greater credit to the greater man. So, in choosing the subjects for our investigation, let us, if possible, work upon those subjects which will finally give us an advanced knowledge of some great subject. I am aware that we cannot always do this: our ideas will often flow in side channels: but, with the great problems of the Universe before us, we may sometime be able to do our share toward the greater end.

What is matter; what is gravitation; what is ether and the radiation through it; what is electricity and magnetism; how are these connected together and what is their relation to heat? These are the greater problems of the universe. But many infinitely smaller problems we must attack and solve before we can even guess at the solution of the greater ones.

In our attitude toward these greater problems how do we stand and what is the foundation of our knowledge?

Newton and the great array of astronomers who have succeeded him have proved that, within planetary distances, matter attracts all others with a force varying inversely as the square of the distance. But what sort of proof have we of this law? It is derived from astronomical observations on the planetary orbits. It agrees very well within these immense spaces; but where is the evidence that the law holds for smaller distances? We measure the lunar distance and the size of the earth and compare the force at that dis-

tance with the force of gravitation on the earth's surface. But to do this we must compare the matter in the earth with that in the sun. This we can only do by *assuming* the law to be proved. Again, in descending from the earth's gravitation to that of two small bodies, as in the Cavendish experiment, we *assume* the law to hold and deduce the mass of the earth in terms of our unit of mass. Hence, when we say that the mass of the earth is $5\frac{1}{2}$ times that of an equal volume of water we *assume* the law of gravitation to be that of Newton. Thus a proof of the law from planetary down to terrestrial distances is physically impossible.

Again, that portion of the law which says that gravitational attraction is proportional to the quantity of matter, which is the same as saying that the attraction of one body by another is not affected by the presence of a third, the feeble proof that we give by weighing bodies in a balance in different positions with respect to each other cannot be accepted on a larger scale. When we can tear the sun into two portions and prove that either of the two halves attracts half as much as the whole, then we shall have a proof worth mentioning.

Then as to the relation of gravitation and time what can we say? Can we for a moment suppose that two bodies moving through space with great velocities have their gravitation unaltered? I think not. Neither can we accept Laplace's proof that the force of gravitation acts instantaneously through space, for we can readily imagine some compensating features unthought of by Laplace.

How little we know then of this law which has been under observation for two hundred years!

Then as to matter itself how have our views changed and how are they constantly changing. The round hard atom of Newton which God alone could break into pieces has become a molecule composed of many atoms, and each of these smaller atoms has become so elastic that after vibrating 100,000 times its amplitude of vibration is scarcely diminished. It has become so complicated that it can vibrate with as many thousand notes. We cover the atom with patches of electricity here and there and make of it a system compared with which the planetary system, nay the universe itself, is simplicity. Nay more: some of us even claim the power, which Newton attributed to God alone, of breaking the atom into smaller

pieces whose size is left to the imagination. Where, then, is that person who ignorantly sneers at the study of matter as a material and gross study? Where, again, is that man with gifts so God-like and mind so elevated that he can attack and solve its problem?

To all matter we attribute two properties, gravitation and inertia. Without these two matter cannot exist. The greatest of the natural laws states that the power of gravitational attraction is proportional to the mass of the body. This law of Newton, almost neglected in the thoughts of physicists, undoubtedly has vast import of the very deepest meaning. Shall it mean that all matter is finally constructed of uniform and similar primordial atoms, or can we find some other explanation?

That the molecules of matter are not round, we know from the facts of crystallography and the action of matter in rotating the plane of polarization of light.

That portions of the molecules and even of the atoms are electrically charged, we know from electrolysis, the action of gases in a vacuum tube, and from the Zeeman effect.

That some of them act like little magnets, we know from the magnetic action of iron, nickel, and cobalt.

That they are elastic the spectrum shows, and that the vibrating portion carries the electric charge with it is shown by the Zeeman effect.

Here, then, we have made quite a start in our problem: but how far are we from the complete solution? How can we imagine the material of which ordinary or primordial atoms are made, dealing as we do only with aggregations of atoms alone? Forever beyond our sight, vibrating an almost infinite number of times in a second, moving hither and yon with restless energy at all temperatures beyond the absolute zero of temperature, it is certainly a wonderful feat of human reason and imagination that we know as much as we do at present. Encouraged by these results, let us not linger too long in their contemplation but press forward to the new discoveries which await us in the future.

Then as to electricity, the subtle spirit of the amber, the demon who reached out his gluttonous arms to draw in the light bodies within his reach, the fluid which could run through metals with the greatest ease but could be stopped by a frail piece of glass! Where

is it now? Vanished, thrown on the waste heap of our discarded theories, to be replaced by a far nobler and exalted one of action in the ether of space.

And so we are brought to consider that other great entity—the ether: filling all space without limit, we imagine the ether to be the only means by which two portions of matter distant from each other can have any mutual action. By its means we imagine every atom in the universe to be bound to every other atom by the force of gravitation and often by the force of magnetic and electric action, and we conceive that it alone conveys the vibratory motion of each atom or molecule out into space to be ever lost in endless radiation, passing out into infinite space or absorbed by some other atoms which happen to be in its path. By it all electromagnetic energy is conveyed, from the feeble attraction of the rubbed amber, through the many thousand horse-power conveyed by the electric wires from Niagara, to the mighty rush of energy always flowing from the Sun in a flood of radiation. Actions feeble and actions mighty, from inter-molecular distances through inter-planetary and inter-stellar distances until we reach the mighty distances which bound the Universe—all have their being in this wonderful ether.

And yet, however wonderful it may be, its laws are far more simple than those of matter. Every wave in it, whatever its length or intensity, proceeds onwards in it according to well known laws, all with the same speed, unaltered in direction, from its source in electrified matter to the confines of the Universe, unimpaired in energy unless it is disturbed by the presence of matter. However the waves may cross each other, each proceeds by itself without interference with the others.

So with regard to gravitation, we have no evidence that the presence of a third body affects the mutual attraction of two other bodies, or that the presence of a third quantity of electricity affects the mutual attraction of two other quantities. The same for magnetism.

For this reason the laws of gravitation and of electric and magnetic action including radiation are the simplest of all laws when we confine them to a so-called vacuum, but become more and more complicated when we treat of them in space containing matter.

Subject the ether to immense electrostatic magnetic or gravitational

forces and we find absolutely no signs of its breaking down or even a change in its properties. Set it into vibration by means of an intensely hot body like that of the sun and it conveys many thousand horsepower for each square foot of surface as quietly and with apparently as unchanged laws as if it were conveying the energy of a tallow dip.

Again, subject a millimeter of ether to the stress of many thousand, nay even a million, volts and yet we see no signs of breaking down.

Hence the properties of the ether are of ideal simplicity and lead to the simplest of natural laws. All forces which act at a distance always obey the law of the inverse square of the distance and we have also the attraction of any number of parts placed near each other equal to the arithmetical sum of the attractions when those parts are separated. So also the simple law of ethereal waves which has been mentioned above.

At the present time, through the labors of Maxwell supplemented by those of Hertz and others, we have arrived at the great generalization that all wave disturbances in the ether are electromagnetic in their nature. We know of little or no ethereal disturbance which can be set up by the motion of matter alone: the matter must be electrified in order to have sufficient hold on the ether to communicate its motion to the ether. The Zeeman effect even shows this to be the case where molecules are concerned and when the period of vibration is immensely great. Indeed the experiment on the magnetic action of electric convection shows the same thing. By electrifying a disc in motion it appears as if the disc holds fast to the ether and drags it with it, thus setting up the peculiar ethereal motion known as magnetism.

Have we not another case of a similar nature when a huge gravitational mass like that of the earth revolves on its axis? Has not matter a feeble hold on the ether sufficient to produce the earth's magnetism?

But the experiment of Lodge to detect such an action apparently showed that it must be very feeble. Might not his experiment have succeeded had he used an electrified revolving disc?

To detect something dependent on the relative motion of the ether and matter has been and is the great desire of physicists. But we always find that, with one possible exception, there is always

some compensating feature which renders our efforts useless. This one experiment is the aberration of light, but even here Stokes has shown that it may be explained in either of two ways: first, that the earth moves through the ether of space without disturbing it, and second, if it carries the ether with it by a kind of motion called irrotational. Even here, however, the amount of action probably depends upon *relative* motion of the luminous source to the recipient telescope.

So the principle of Doppler depends also on this relative motion and is independent of the ether.

The result of the experiments of Foucault on the passage of light through moving water can no longer be interpreted as due to the partial movement of the ether with the moving water, an inference due to imperfect theory alone. The experiment of Lodge, who attempted to set the ether in motion by a rapidly rotating disc, showed no such result.

The experiment of Michelson to detect the ethereal wind, although carried to the extreme of accuracy, also failed to detect any relative motion of the matter and the ether.

But matter with an electrical charge holds fast to the ether and moves it in the manner required for magnetic action,

When electrified bodies move together through space or with reference to each other we can only follow their mutual actions through very slow and uniform velocities. When they move with velocities comparable with that of light, equal to it or even beyond it, we calculate their mutual actions or action on the ether only by the light of our imagination unguided by experiment. The conclusions of J. J. Thomson, Heaviside, and Hertz are all results of the imagination and they all rest upon assumptions more or less reasonable but always assumptions. A mathematical investigation always obeys the law of the conservation of knowledge: we never get out more from it than we put in. The knowledge may be changed in form, it may be clearer and more exactly stated, but the total amount of the knowledge of nature given out by the investigation is the same as we started with. Hence we can never predict the result in the case of velocities beyond our reach, and such calculations as the velocity of the cathode rays from their electro-

magnetic action has a great element of uncertainty which we should do well to remember.

Indeed, when it comes to exact knowledge, the limits are far more circumscribed.

How is it, then, that we hear physicists and others constantly stating what will happen beyond these limits? Take velocities, for instance, such as that of a material body moving with the velocity of light. There is no known process by which such a velocity can be obtained even though the body fell from an infinite distance upon the largest aggregation of matter in the Universe. If we electrify it, as in the cathode rays, its properties are so changed that the matter properties are completely masked by the electromagnetic.

It is a common error which young physicists are apt to fall into to obtain a law, a curve, or a mathematical expression for given experimental limits and then to apply it to points outside those limits. This is sometimes called extrapolation. Such a process, unless carefully guarded, ceases to be a reasoning process and becomes one of pure imagination specially liable to error when the distance is too great.

But it is not my purpose to enter into detail. What I have given suffices to show how little we know of the profounder questions involved in our subject.

It is a curious fact that, having minds tending to the infinite, with imaginations unlimited by time and space, the limits of our exact knowledge are very small indeed. In time we are limited by a few hundred or possibly thousand years: indeed the limit in our science is far less than the smaller of these periods. In space we have exact knowledge limited to portions of our earth's surface and a mile or so below the surface, together with what little we can learn from looking through powerful telescopes into the space beyond. In temperature our knowledge extends from near the absolute zero to that of the sun, but exact knowledge is far more limited. In pressures we go from the Crookse vacuum still containing myriads of flying atoms to pressures limited by the strength of steel, but still very minute compared with the pressure at the center of the earth and sun, where the hardest steel would flow like the most limpid water. In velocities we are limited to a few miles per second.

In forces to possibly 100 tons to the square inch. In mechanical rotations to a few hundred times per second.

All the facts which we have considered, the liability to error in whatever direction we go, the infirmity of our minds in their reasoning power, the fallibility of witnesses and experimenters, lead the scientist to be specially skeptical with reference to any statement made to him or any so-called knowledge which may be brought to his attention. The facts and theories of our science are so much more certain than those of history, of the testimony of ordinary people on which the facts of ordinary history or of legal evidence rest, or of the value of medicines to which we trust when we are ill, indeed to the whole fabric of supposed truth by which an ordinary person guides his belief and the actions of his life, that it may seem ominous and strange if what I have said of the imperfections of the knowledge of physics is correct. How shall we regulate our mind with respect to it: there is only one way that I know of and that is to avoid the discontinuity of the ordinary, indeed the so-called cultivated legal mind. There is no such thing as absolute truth and absolute falsehood. The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error.

The ordinary crude mind has only two compartments, one for truth and one for error; indeed the contents of the two compartments are sadly mixed in most cases; the ideal scientific mind, however, has an infinite number. Each theory or law is in its proper compartment indicating the probability of its truth. As a new fact arrives the scientist changes it from one compartment to another so as, if possible, to always keep it in its proper relation to truth and error. Thus the fluid nature of electricity was once in a compartment near the truth. Faraday's and Maxwell's researches have now caused us to move it to a compartment nearly up to that of absolute error.

So the law of gravitation within planetary distances is far toward absolute truth, but may still need amending before it is advanced farther in that direction.

The ideal scientific mind, therefore, must always be held in a

state of balance which the slightest new evidence may change in one direction or another. It is in a constant state of skepticism, knowing full well that nothing is certain. It is above all an agnostic with respect to all facts and theories of science as well as to all other so-called beliefs and theories.

Yet it would be folly to reason from this that we need not guide our life according to the approach to knowledge that we possess. Nature is inexorable ; it punishes the child who unknowingly steps off a precipice quite as severely as the grown scientist who steps over, with full knowledge of all the laws of falling bodies and the chances of their being correct. Both fall to the bottom and in their fall obey the gravitational laws of inorganic matter, slightly modified by the muscular contortions of the falling object, but not in any degree changed by the previous belief of the person. Natural laws there probably are, rigid and unchanging ones at that. Understand them and they are beneficent : we can use them for our purposes and make them the slaves of our desires. Misunderstand them and they are monsters who may grind us to powder or crush us in the dust. Nothing is asked of us as to our belief : they act unswervingly and we must understand them or suffer the consequences. Our only course, then, is to act according to the chances of our knowing the right laws. If we act correctly, right ; if we act incorrectly, we suffer. If we are ignorant we die. What greater fool, then, than he who states that belief is of no consequence provided it is sincere.

An only child, a beloved wife, lies on a bed of illness. The physician says that the disease is mortal ; a minute plant called a microbe has obtained entrance into the body and is growing at the expense of its tissues, forming deadly poisons in the blood or destroying some vital organ. The physician looks on without being able to do anything. Daily he comes and notes the failing strength of his patient and daily the patient goes downward until he rests in his grave. But why has the physician allowed this ? Can we doubt that there is a remedy which shall kill the microbe or neutralize its poison ? Why, then, has he not used it ? He is employed to cure but has failed. His bill we cheerfully pay because he has done his best and given a chance of cure. The answer is *ignorance*. The remedy is yet unknown. The physician is

waiting for others to discover it or perhaps is experimenting in a crude and unscientific manner to find it. Is not the inference correct, then, that the world has been paying the wrong class of men? Would not this ignorance have been dispelled had the proper money been used in the past to dispel it? Such deaths some people consider an act of God. What blasphemy to attribute to God that which is due to our own and our ancestors' selfishness in not founding institutions for medical research in sufficient number and with sufficient means to discover the truth. Such deaths are murder. Thus the present generation suffers for the sins of the past and we die because our ancestors dissipated their wealth in armies and navies, in the foolish pomp and circumstance of society, and neglected to provide us with a knowledge of natural laws. In this sense they were the murderers and robbers of future generations of unborn millions, and have made the world a charnel house and place of mourning where peace and happiness might have been. Only their ignorance of what they were doing can be their excuse, but this excuse puts them in the class of bores and savages who act according to selfish desire and not to reason and to the calls of duty. Let the present generation take warning that this reproach be not cast on it, for it cannot plead ignorance in this respect.

This illustration from the department of medicine I have given because it appeals to all. But all the sciences are linked together and must advance in concert. The human body is a chemical and physical problem, and these sciences must advance before we can conquer disease.

But the true lover of physics needs no such spur to his actions. The cure of disease is a very important object and nothing can be nobler than a life devoted to its cure.

The aims of the physicist, however, are in part purely intellectual: he strives to understand the Universe on account of the intellectual pleasure derived from the pursuit, but he is upheld in it by the knowledge that the study of nature's secrets is the ordained method by which the greatest good and happiness shall finally come to the human race.

Where, then, are the great laboratories of research in this city, in this country, nay, in the world? We see a few miserable structures here and there occupied by a few starving professors who are

nobly striving to do the best with the feeble means at their disposal. But where in the world is the institute of pure research in any department of science with an income of \$100,000,000 per year. Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But \$100,000,000 per year is but the price of an army or of a navy designed to kill other people. Just think of it, that one per cent of this sum seems to most people too great to save our children and descendants from misery and even death!

But the twentieth century is near—may we not hope for better things before its end? May we not hope to influence the public in this direction?

Let us go forward, then, with confidence in the dignity of our pursuit. Let us hold our heads high with a pure conscience while we seek the truth, and may the American Physical Society do its share now and in generations yet to come in trying to unravel the great problem of the constitution and laws of the Universe.

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J. S. AMES

M. I. PUPIN

ERNEST MERRITT

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American Physical Society.

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J. S. AMES, M. I. PUPIN, ERNEST MERRITT.

The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Third Meeting.

MORNING SESSION.

The regular Annual Meeting was held in Room 304, Fayerweather Hall, Columbia University, New York City, on Thursday, December 28, 1899, with President Henry A. Rowland in the chair.

The Society proceeded at once to its scientific program. The following papers were read during the morning session :

Note on the Electric Magnetic Field surrounding a wire carrying an Electric Current. W. S. Franklin.

On the Influence of Electrification upon the Surface Tension of Water and Mercury. Ernest Merritt and S. J. Barnett.

The Specific Heats of Non-electrolytes in Solution. W. F. Magie.
(Read by title.)

Pressure in the Electric Spark. J. F. Mohler.

The Radiation of a Black Body. C. E. Mendenhall.

AFTERNOON SESSION.

In the afternoon the Society accepted the invitation of The American Mathematical Society to attend the address of President R. S. Woodward, entitled "The Century's Progress in Applied Mathematics."

At the close of President Woodward's address a joint session of the Mathematical Society and Physical Society was held, during which the following paper was read :

The Propagation of Electric Waves along Non-uniform Conductors, by M. I. Pupin.

The Physical Society then adjourned to Room 304 and proceeded with its program, the papers read being as follows :

On Entropy. A. G. Webster.

On the Slit Method of Calibration of Prisms. Dewitt B. Brace.

Note on the Production of an Electric Current by Moving Matter through Ether. H. S. Rowland.

Adjourned.

Minutes of the Fourth Meeting.**MORNING SESSION.**

Regular meeting held in Fayerweather Hall, Columbia University, New York City, on February 24, 1900.

The meeting came to order at 11 o'clock. In the absence of the President and Vice-President, Mr. Magie was made temporary chairman.

The following papers were presented during the morning session :

The Specific Heats of Non-electrolytes in Solution. W. F. Magie.

The General Plan of the Magnetic Survey of the United States. L. A. Bauer.

AFTERNOON SESSION.

At 2 o'clock the Society met with the American Mathematical Society. The following paper was presented at the joint session :

The Results of Seven Years' Observation for Variation of Latitude and the Constant of Aberration, made at the Columbia University. J. K. Rees.

At the conclusion of Mr. Rees's paper, the Physical Society re-assembled in Room 304. The following papers were then presented :

On the Temperature of the Acetylene Flame. E. L. Nichols.

Use of Condenser and Ballistic Galvanometer in Observation of Atmospheric Electricity. F. L. Tufts.

Transmission of the Ionized Exhalations of Phosphorous through Air and other Media, C. Barus. (Read by title.)

On recommendation of the Council it was resolved that a committee to be appointed consisting of Messrs. Webster, Woodward, and Ames, to draw up a memorial to Congress on behalf of the Physical Society, urging the establishment of a Bureau of Weights and Measures in connection with the United States Geodetic Survey.

Adjourned.

Minutes of the Fifth Meeting.**MORNING SESSION.**

A regular meeting was held in Fayerweather Hall, Columbia University, New York City, on April 28, 1900.

In the absence of the President and Vice-President, Mr. Hallock was made temporary chairman. Mr. Webster was elected temporary secretary.

The following papers were read during the morning session :

A New Method for the Calibration of Standard Rheostats. H. C. Parker.

The Electrical Resistance of Thin Films Deposited by Kathode Discharge. A. C. Longden.

AFTERNOON SESSION.

The Society met with the American Mathematical Society from 2 till 3 p. m., Mr. Hallock in the chair.

The following papers were read in joint session :

A Possible Explanation of the Eleven Year Period of Sun-Spot Activity. E. W. Brown.

An Elementary Method of Integrating certain Linear Differential Equations. R. L. Woodward.

At the conclusion of the joint session the Physical Society reassembled in Room 304.

The report of the committee on the memorial to congress concerning the National Standardizing Laboratory was presented by Mr. Webster. The report was adopted, and it was voted that it should be laid before Congress with the cordial approval of the Society of the bill now pending in Congress.

It was voted that the Program Committee of the Council be authorized to co-operate with the officers of Section B of the American Association for the Advancement of Science in arranging for a joint meeting with that section in the summer.

Papers read :

Some Novel Experiments in Stationary Sound Waves. Bergen Davis.

On the Octave as an Overtone of a Tuning Fork. William Hallock.

Some Quantitative Experiments on Diffraction of Sound. A. G. Webster.

A simple Experiment illustrating the Effect of the Reaction of the Secondary on the Self-induction of a Primary Coil. A. G. Webster.

Adjourned.

AN ATTEMPT TO DETECT ANY VISCOSITY OR FRICTION IN THE ETHER.*

(Abstract.)

H. A. ROWLAND AND N. E. GILBERT.

When an electric current in a coil maintains a magnetic field in the ether or in iron we imagine that the ether or something about the molecules of the iron is in rotary motion. If there is any friction connected with this motion, the energy must be derived from the current in the wire and the resistance of the wire will apparently be greater when maintaining a field than when not. The resistance of a coil maintaining a magnetic field was measured. Then the current in half the coil was reversed and the resistance measured again. No difference was detected.

An attempt to account for the magnetism of the earth. The absence of any reasonable explanation of the cause of the earth's magnetism led to the question whether, as the earth rotates on its axis, the positive and negative electricities are carried along at the same rate. If the positive electricity lags behind the negative we have a current flowing around the earth from east to west which will partially account for the magnetism.

A brass wheel was made and a coil of wire so wound on it that it would move longitudinally when the wheel was rotated. The coil was of rectangular cross-section and enclosed on three sides by the brass of the wheel.

No appreciable current was obtained when the wheel was rotated.

Further experiments on the connection between moving matter and the ether.

Another wheel was made with a broad face; and the wire was wound on this in a single layer. Experiments with this wheel are still in progress, and seem to indicate a slight effect in the direction which would account for the greater part of the earth's magnetism.

*Presented at the meeting held on Oct. 28, 1899.

ELECTROLYTIC RECTIFIER OF ALTERNATING CURRENTS.*

(Abstract.)

M. I. PUPIN.

The electrolytic cell employed is represented in Fig. 1; ab is a platinum wire, one extremity b of which is sealed in a glass tube and smoothly polished off, so that the cross-section only of the wire is exposed. This forms one electrode of the cell. The other electrode is a platinum plate C or a platinum wire. The liquid is dilute sulphuric acid.

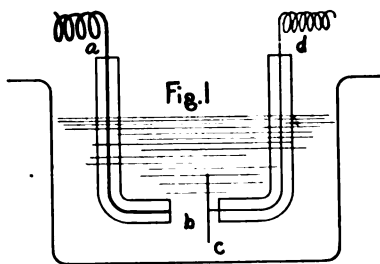
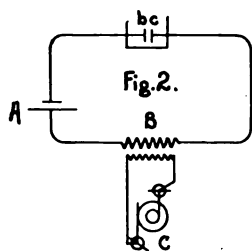


Fig. 2 illustrates how this cell is employed for rectification; bc is the rectifying cell. A is a galvanic cell the electromotive force of which is about equal to the decomposition value of the counter-electromotive force of the polarization of cell bc . The circuit containing these two cells has an asymmetrical reactance, because the cell bc has electrostatic capacity when the $E.M.F.$ acts in one direction, but not when it acts in the opposite direction.



If the capacity reactance is large in comparison to the inductance reactance and the resistance there will be efficient rectification of the

alternating current which the generator C tends to produce in the circuit $A B b c$.

It is evident that the higher the frequency the smaller must be the area b . I have succeeded in rectifying Hertzian oscillations by using for b a platinum wire of .001 inches in diameter. This cell has been employed by me successfully over five years.

*Presented at the meeting held on Oct. 28, 1899.

ON THE DEDUCTION OF THE EQUATIONS OF ELECTRO-MAGNETIC WAVES.*

(Abstract)

A. G. WEBSTER.

An attempt to explain in an elementary manner the nature of electromagnetic waves, and to deduce the equations. Two fundamental experiments of Ampère and Faraday are assumed. According to Ampère, a straight current is surrounded by circular lines of force positively linked with it. Assuming that the current is equivalent magnetically to a line of positive charges moving in its direction, and that each is a source of divergence of electric induction, we may express the law by saying that lines of electric induction moving at right angles to their own direction generate magnetic lines of force perpendicular to themselves and to the motion.

In Faraday's experiment consider a magnetic pole moving through the center of a conducting circle perpendicular to its plane. We may again describe the fields by stating that magnetic lines of induction moving perpendicularly to themselves generate electric lines of force perpendicular to the magnetic lines and to the motion. The directions are given by the same convention as before, remembering that the motion vector belongs to that field which generates the other.

Consider now an electric field directed vertically upward to be suddenly generated in a certain region. This is the same as if vertical lines of force rallied toward the center of the region. Applying the previous reasoning this is found to produce horizontal magnetic lines, directed backwards from the paper on the right, forward on the left. Consider now the generation of the horizontal magnetic field on the right. This is the same as if horizontal magnetic lines rallied on it. Applying the reasoning again we find an electric field generated, pointing upwards still farther to the right, and thus passing the original field on, and downward on the left, thus destroying the original field. Similarly at other points, so that the wave is transmitted outwards from the original disturbed region.

*Presented at the meeting held on Oct. 28, 1899.

Quantitatively, assume the fields produced by the motion to be proportional to the moving field and velocity of motion. Consider a rectangle normal to the Z -axis, whose sides A, B, C, D , are of lengths dx, dy . The electric flux is $3 dx dy$.

By preceding rules, fields produced at points on different sides are

$$\begin{aligned} A, \quad L &= v_A 3_A, \\ C, \quad - \left(L + \frac{\delta L}{\delta y} dy \right) &= v_C 3_C, \\ D, \quad - M &= v_D 3_D, \\ B, \quad \left(M + \frac{\delta M}{\delta n} \delta n \right) &= v_B 3_B. \end{aligned}$$

But the flux entering the rectangle through one side in the time dt is 3 times the length of the side times $v dt$. Consequently through all

$$\frac{\delta 3}{\delta t} dt dx dy = dt \left(3_A v_A dx + 3_B v_B dy + 3_C v_C dx + 3_D v_D dy \right)$$

Substituting above values,

$$\left(\frac{\delta M}{\delta n} - \frac{\delta L}{\delta y} \right) = \frac{\delta 3}{\delta t}$$

the differential equation. Similarly for the others.

ON A NEW APPARATUS TO SHOW THE MOTION OF THE TOP.*

(Abstract)

A. G. WEBSTER.

A substantial cast-iron disk, fixed to an axis half a meter long, suspended by a universal joint from the vertical shaft of an electric motor, by which the velocity of spinning is maintained constant. At the end of the shaft is a brush dipped in ink, or a sliding steel point, marking on a smoked glass. By means of a rising table the curves are drawn. They are also projected on a screen. The curves are of three types, cuspidal, looped, or non-looped, according to the sidewise impetus given the pendulum at starting. Similar curves have been published by Bobyleff and Merritt.

*Presented at the meeting held on Oct. 28, 1899.

NOTE ON THE DISTRIBUTION OF ELECTRIC FIELD e ,
AND OF MAGNETIC FIELD f NEAR A CONDUCTOR IN
WHICH AN ELECTRIC CURRENT IS FLOWING.*

(Abstract.)

W. S. FRANKLIN.

The discussion was limited to the case of steady current. The differential equations for e and for f both inside of conductor and outside of conductor were derived, and the boundary conditions formulated. In case the region in which the distribution of e and f is to be determined is connected to the region in which the generator is situated then the complete specification of the boundary conditions is not possible because of our lack of knowledge of what takes place in a generator. In view of this fact it was pointed out that e and f could be completely determined only in regions entirely enclosed by conducting sheets, or in regions which communicate with the region of the generator through narrow channels of dielectric so that the boundary condition at the entrance to this channel may be represented by an electrical doublet.

The distribution of e and f was determined for a number of special cases as follows :

(a) The region enclosed in a spherical shell, current entering the shell at one point and leaving it at the opposite point.

(b) The region enclosed in an infinite cylindrical shell, the current entering the shell along a given straight line and leaving it along the straight line on the opposite side of the shell.

(c) The region enclosed by a conducting shell of such shape that lines of force from an electrical doublet (point doublet or linear doublet) lie in the shell, the thickness of the shell at each point being inversely proportional to the intensity of the field at that point due to the doublet. Current enters the shell at one pole of the doublet and leaves the shell at the other pole of the doublet. This case is of peculiar interest inasmuch as there are no electric charges anywhere on the conducting shell so that the electric field near the shell is everywhere parallel to the surface of the shell.

*Presented at the meeting held on Dec. 28, 1899.

(d) The region between three infinite plane conducting sheets, two of the sheets being parallel and the other at right angles to the two.

It was pointed out in general that the lines of electric force terminate in stationary charges and that the electric field surrounding a conductor carrying current might be actually reproduced by a system of stationary charges.

PRESSURE IN THE ELECTRIC SPARK.*

(Abstract.)

JOHN FRED MOHLER.

When the electric spark passes between electrodes a pressure is developed in the path of the spark owing to the sudden rise in temperature and the inertia of the gas. This pressure has been measured¹ by indirect mechanical means, and the results show such peculiarities that I attempted to measure this pressure in another indirect way.

In former papers² I have showed that when the medium surrounding the arc is under pressure there is a displacement of the lines of the spectrum produced, varying with the element and the wave length but for any one line proportional to the pressure of the medium.

For cadmium this shift of the lines is about .008 of an Angström unit per atmosphere pressure and for iron the shift is about one-fourth as much. My method then was to photograph the spark spectra of cadmium and iron and compare the position of the lines obtained with their position in the arc spectrum at atmospheric pressure. This measured shift divided by the shift as given above for one atmosphere gave me the pressure in the spark. By varying the metal, the capacity, the medium and the pressure of the medium I obtained the following results :

*Presented at the meeting held on Dec. 28, 1899.

¹Harchek and Mache, *Astroph. Journal*, May 1899. Sitz, der K. der W. 167.

²Springfield meeting A. A. S. 1895, *Astroph. Journal*, Feb., 1896, also Oct., 1896. Circular J. H. U., Feb., 1896.

Element.	Capacity in Metres.	Medium.	Presence of the Medium.	Measured Shift in Ålögstrom units.	Pressure in the Spark in Atmosphere.
Cd.....	29	Air	1 at.	.026	3.25 at.
Cd.....	58	Air	1 at.	.044	5.5 at.
Cd.....	265	Air	1 at.	.084	10.5 at.
Cd.....	294	Air	1 at.	.088	11. at.
Fe.....	58	Air	1 at.	.011	5.5 at.
Cd.....	58	Air	4 at.	.160	20. at.
Cd.....	58	Co ₂	1 at.	.067	8.4 at.
Cd.....	265	Co ₂	1 at.	.116	14.5 at.

The above results show that the pressure increases with capacity but not directly. Also that approximately the pressure increases with the density of the surrounding medium. Of course these values are only the average pressures as the lines are photographed. The general character of the lines of a spark spectrum indicate a possible large range of pressure of which the above results are the average.

THE INFLUENCE OF ELECTRIFICATION UPON THE SURFACE TENSION OF WATER AND MERCURY.*

(Abstract.)

ERNEST MERRITT AND SAMUEL J. BARNETT.

Since an electric charge is known to reside on the surface of a conductor, it is not unnatural to expect that the electrification of a liquid should cause some change in its surface tension. In fact, there are many well known phenomena that suggest such a change. Such phenomena, however, are undoubtedly due in large part to the electrostatic forces that are developed by the presence of a charge upon the liquid surface. It is readily seen that if the surface is convex, the effect of the electrostatic forces would be similar to that produced by a weakening of the surface film

To determine whether there exists a true effect of electrification upon the surface tension of a liquid, investigations must be made by methods which make the calculation of the purely electrostatic effect feasible, so that it may be eliminated from the total effect.

*Presented at the meeting held on Dec. 28, 1899.

Experiments having this object in view were described by one of us in a recent paper.¹ The results showed that the effect in question, if it exists at all, is much smaller than previously supposed; but as the theory of the method used had not been fully developed at the time of publication, no more definite conclusion could then be drawn. It is the object of the present communication to complete the discussion of these experiments.

In the experiments referred to, the tension of the liquid surface was investigated by the method of capillary ripples. When the liquids were electrically charged the velocity of the capillary waves was found to be less than when the surface was unelectrified. In the case of water, this change would correspond to a diminution in surface tension of about 4% for a surface density of 1.75 electrostatic units. It is to be observed, however, that the results cited do not necessarily prove the existence of a real change in surface tension; for the electrostatic forces acting upon a charged surface would cause a diminution in the velocity of the capillary ripples, even if the surface tension remained unaltered. In order to determine whether a real change in surface tension results from electrification, we must take account of the electrostatic forces in deriving the relation between surface tension and velocity.

To determine the velocity of capillary ripples, we have the general equation

$$\frac{\delta p}{\rho} = -gh - \frac{d\phi}{dt} \quad (1)$$

where ρ is the density of the liquid, h the displacement of the point considered above its equilibrium position, p the resulting increment of pressure at the surface, ϕ the velocity potential, and g the acceleration of gravity.

If p is due to capillarity only, we have

$$\delta p = -T \frac{\delta^2 h}{\delta x^2}$$

T being the surface tension; and equation (1) becomes

$$\frac{T \delta^2 h}{\rho \delta x^2} = gh + \frac{d\phi}{dt} \quad (2)$$

In the case of plane sine waves in a liquid of sufficient depth this gives for the surface tension

¹ Barnett. Physical Review, Vol. VI, p. 257, 1898.

$$T = \frac{\rho \lambda^2}{2\pi} \left(\lambda n^2 - \frac{g}{2\pi} \right) \quad (3)$$

where n is the frequency of the waves. When the surface of the liquid is charged, however, a pressure of $-\frac{2\pi\sigma^2}{K}$ is developed in addition to that due to capillarity, σ being the electric surface density and K the dielectric constant of the medium above the waves. In the place of equation (2) we have therefore, in this case,

$$\frac{T \delta^2 h}{\rho \delta x^2} + \frac{2\pi}{K} (\sigma^2 - \sigma_0^2) = gh + \frac{d\phi}{dt} \quad (4)$$

where σ_0 is the surface density on the undistorted surface.

For the method of determining σ as a function of h reference must be made to the complete paper. Under the conditions of the experiment, and for waves of small amplitude, it was found that

$$\sigma = \sigma_0 \left(1 + \frac{2\pi h}{\lambda} \right)$$

and equation 3 therefore becomes

$$\frac{T \delta^2 h}{\rho \delta x^2} = \left(g - \frac{8\pi^2 \sigma_0^2}{K \lambda \rho} \right) h + \frac{d\phi}{dt} \quad (5)$$

Upon comparing this with equation (2) it appears that the effect of electrifying the surface is to alter the velocity of the waves in the same sense and to the same extent as would a diminution of the acceleration of gravity by $\frac{8\pi^2 \sigma_0^2}{K \lambda \rho}$.

The corrected expressions for the surface tension is therefore,

$$T = \frac{\rho \lambda^2}{2\pi} \left(\lambda n^2 - \frac{g}{2\pi} \right) + \frac{2\lambda \sigma_0^2}{K} \quad (6)$$

By the aid of the experimental data obtained by Mr. Barnett the true surface tension of water and mercury have been computed for different values of the electric surface density. The results are given in Tables I and II expressed in terms of the surface tension of the uncharged liquids.

TABLE I.—WATER.

V (Volts)	σ_0 (Electrostatic)	T Apparent	T Corrected
0	0.00	100.00%	100.00%
9000	0.58	99.61	.06
12000	0.77	99.29	.08
15000	0.97	98.98	.23
18000	1.17	98.37	.19
21000	1.36	97.69	.15
24000	1.56	96.94	.16
27000	1.74	96.13	100.13

TABLE II.—MERCURY.

V (Volts)	σ_0 (Electrostatic)	T Apparent	T Corrected
0	0.00	100.00%	100.00%
9000	0.70	99.92	.01
12000	0.93	.88	.04
15000	1.17	.83	.08
18000	1.39	.75	.10
21000	1.63	.61	.10
24000	1.87	.44	.08
27000	2.09	.25	.05
30000	2.33	.08	100.07

The final column of Table I gives for the surface tension of an electrified water surface values ranging from 0.06% to 0.23% higher than that of the uncharged surface, the average table being about 1/7% higher; while the corresponding column of Table II

gives for the tension of an electrified mercury surface values from 0.01% to 0.10% higher than that for no electrification—the mean being about 1/15% higher. The fact that the very small variation follows no law in either case, being often less for high than for low electric surface densities, would indicate that it possesses no significance and is due wholly to experimental errors.

The complete investigation, therefore, while not excluding the possibility of discovering an effect of electrification upon surface tension by the use of improved methods and still more intense charges, itself gives no support to the view that such an effect exists.

ON THE USE OF THE SLIT IN PHOTOMETRIC COMPARISONS.

D. B. BRACE.

The method of Vierordt of using the slit width directly for measuring the intensity in color comparison, while perhaps the simplest yet proposed, may introduce errors exceeding ten per cent., even for bilateral slits. This is not due to errors of the screw or of the zero settings, but to the slope of the luminosity curve in different parts of the spectrum, a point overlooked by him and many observers after him.

A consideration of the curve of luminosity of any source will show that, except where this is parallel to the axis of the screw, a variation in the width of an unilateral slit will cause the mean centre of the color to shift, so that variation in intensity is not proportional to the variation in the slit width. The error in this case is so large that an unilateral slit can rarely be used. The use of a bilateral slit does not in general eliminate this error excepting where the slope of the curve is a straight line. In this case the variation of intensity and slit width are proportional. An examination of various curves of luminosity shows that this error is always present to an amount dependent upon the slit width and the part of the spectrum compared. This error together with the variation of the screw, the parallelism of the jaws and the uncertainty of zero, the internal prismatic and surface absorption of the prism, etc., renders the accuracy of the method as used by Vierordt much inferior to the sensibility now attainable with the cubical viewing screen of Lummer & Brodhun, or with the dispersion viewing prism of the writer, where the mean errors of the settings can be reduced to less than $\frac{1}{4}$ of one per cent. The loss of light with polarizing systems or with variable rotation sectors is a serious objection, while the latter method of measurement is a tedious process.

The optical calibration of the slit, a method apparently not heretofore used, eliminates the error above referred to and simplifies materially the observations. This is readily accomplished by any of the several methods used for making direct measurements of intensities. In the spectrophotometer of the writer described elsewhere (*Phil. Mag.* Nov. 99; *Astrophysical Jour.*, Jan., 1900.) the two slits are illuminated by constant sources of light. The one which is to illuminate the slit which is to be calibrated should be readily reproduced,—preferably an incandescent filament. The intensity of the other may be varied in any given ratio by varying the distance, using crossed Nicols, or rotating a sector after the method of Talbot. A rotating card board disc notched out into aliquot parts, say into eighths, has been used advantageously. By shifting this the intensity can be varied and thus the settings of the screw of the slit to be calibrated can be made in corresponding ratios. Intermediate values can then be readily interpolated. This process can be repeated for the different colors and thus the true optical values

of the different slit widths determined. Future observations can then be made with the slit alone with much greater rapidity than with the methods mentioned and with equal accuracy.

As the curve of luminosity is dependent in part on subjective conditions and is different in the dichromatic or the monochromatic eye from the normal trichromatic eye, separate calibrations should be made by each individual. Variations in the intensity also affect the slope of the curve. However this is constant over a long period of time for the same source. In case of incandescent filaments the curve is approximately the same for a variation of fifty per cent in the voltage, and for different lamps, so that once the calibration is made it can be relied upon for all future measurements.

When the intensities vary over very wide ranges, a rotating card board sector may be used for any definite ratio of intensity and the slit then set for the finer adjustment. The increase in the quantity of light and the rapidity with which readings can be made by this method commends it over others. With the dispersion viewing prism referred to and the method of calibration here described color comparisons may be readily and accurately made by means of an ordinary spectrometer or spectroscope with the addition of a single collimating telescope.

When two constant radiants are not available, a single one may be used,—for example the acetylene flame from a flat burner placed symmetrically between the two collimators and reflected into the same by mirrors. For comparisons of absolute intensities one or both of the slits may be replaced by incandescent filaments of carbon or of platinum and regulated by resistances to some definite temperature, after the method adopted by the Reichs Anstalt in Berlin with the Platinum Standard.

THE GENERAL PLAN OF THE MAGNETIC SURVEY OF THE UNITED STATES.*

(Abstract.)

L. A. BAUER.

After making a brief statement of the past operations in magnetic work by the United States Coast and Geodetic Survey, the author presented the general plan of a detailed magnetic survey of the United States. Such an undertaking can now be seriously entertained by reason of the enlarged opportunities brought about by the formation of a special division in the United States Coast and Geodetic Survey for magnetic work.

The intention is, first, to make a general magnetic survey, with stations about 30 to 40 miles apart and to have the period of the survey not to extend over 10 to 15 years; this would mean completing about 500 stations per annum. The men assigned for magnetic work will be drawn partly from the Coast and Geodetic Survey and will be partly University men who have a few months available in the course of the year for work of this character.

For the elimination of the countless fluctuations of the earth's magnetism, three or four fixed magnetic observatories, one near Washington City to be known as the Standard Observatory, one on the Pacific Coast, one on the Hawaiian Islands and possibly one in Alaska, will be established. Also temporary observatories will be put in operation for a few months according to the purposes at hand.

Results of recent magnetic work by the United States Coast and Geodetic Survey, illustrated by charts, were briefly presented before the Society, namely the magnetic charts as obtained from the detailed magnetic surveys of Maryland and North Carolina.

* Presented at the meeting held on Feb. 24, 1900.

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1900

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The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Sixth Meeting.

A joint meeting of the American Physical Society and Section B of the American Association for the Advancement of Science was held at Columbia University, New York City, during the week of June 25-30, 1900, the two societies meeting upon alternate days.

In the absence of the President and Vice-President, Mr. Cooley was made temporary chairman.

The following papers were read before the Physical Society :

1. The Anomalous Dispersion of Cyanine. By R. W. Wood and C. E. Magnusson.
2. The Optical Properties of Thin Carbon Films. By R. W. Wood.
3. A Mica Echelon Grating. By R. W. Wood.
4. False Spectra from the Rowland Concave Grating. By Theodore Lyman.
5. The Zeeman Effect. By H. M. Reese.
6. The Spectra of Mercury. By W. B. Huff.
7. Electrical Absorption in Condensers. By L. M. Potts.
8. Polarization of the Solar Corona. By N. E. Dorsey.
9. A Comparison of the Brightness of Prisms and Gratings in Spectrum Work. By N. E. Dorsey.
10. Preliminary Tests on the Efficiency of the Acetylene Flame as a Means of Illumination. By E. L. Nichols.
11. On the Characteristic Equation of Water. By A. D. Risteen.
12. Some Simple Apparatus for the Study of Aerial Vibrations. By F. L. Tufts.
13. The Use of the Bicycle Wheel in Illustrating the Principles of the Gyroscope. By C. T. Knipp.

14. The Effect of Solid Dielectrics in the Production of Electrical Sparks. By W. J. Humphreys.
15. Magnetic Observations on the day of the Eclipse, May 28, 1900. By L. A. Bauer.
16. A Method of Obtaining Brilliance of Concave Grating Spectra. By W. J. Humphreys.

THE RESULTS OF SEVEN YEARS' OBSERVATIONS FOR
VARIATION OF LATITUDE AND THE CONSTANT OF
ABERRATION, MADE AT THE COLUMBIA UNIVERSITY.¹

J. K. REES.

(Abstract.)

From May 1st, 1893, to July 1st, 1894, the observations were made every clear night. After the latter date it was decided to observe four clear nights each half month, whenever possible. All of the observations were made by J. K. Rees, H. Jacoby, and H. S. Davis.

For the purpose of reduction the observations were divided into four series as follows :

Series A. April 24, 1892, to July, 1894-----	818 pairs by Rees.
	302 " Jacoby.
	654 " Davis.
" B. July, 1894, to Jan., 1896-----	771 " Rees.
	310 " Davis.
" C. Jan., 1896, to Jan., 1898-----	1065 " Rees.
	774 " Davis.
" D. Jan., 1898, to Dec., 1899-----	951 " Rees.
	873 " Davis.
Total pairs-----	6518

This table shows the individual observers to have measured :

Rees-----	3605 pairs.
Jacoby-----	302 "
Davis-----	2611 "
Total-----	6518

The computations gave the following table :

¹ Presented at the meeting held on Feb. 24, 1900.

OBSERVATIONS FOR VARIATIONS OF LATITUDE. 35

DATE.	ϕ	$\phi - \phi_0$	No. Pairs	DATE.	ϕ	$\phi - \phi_0$	No. Pairs	DATE.	ϕ	$\phi - \phi_0$	No. Pairs
1893				1895				1897			
May 9	27.222	— .082	77	Aug. 10	27.295	— .009	19	Nov. 26	.089	— .215	38
19	.144	— .160	44	23	27.103	— .201	46	Dec. 10	.193	— .111	13
27	.162	— .142	42					26	27.100	— .204	22
June 8	.178	— .126	59	Sept. 15	26.943	— .361	26	1898			
17	.198	— .106	45	Oct. 1	.996	— .308	38	Jan. 10	.205	— .099	33
28	.259	— .045	32	18	27.111	— .193	55	26	.139	— .165	43
July 8	.262	— .042	30	Nov. 5	.119	— .185	50	Feb. 10	.177	— .127	53
19	.177	— .127	38	18	.063	— .241	36	Mar. 1	.246	— .058	88
26	.141	— .163	46	Dec. 2	.070	— .234	41	17	.169	— .135	25
Aug. 6	.029	— .275	46	1896				April 4	.285	— .019	33
Oct. 6	.377	+ .073	31	Jan. 14	.474	+ .170	37	19	.461	+ .157	22
15	.244	— .060	43	28	.476	+ .172	54	May 12	.365	+ .061	69
30	.241	— .063	44	Feb. 11	.542	+ .238	45	26	.429	+ .125	28
Nov. 9	.111	— .193	46	22	.600	+ .296	41	June 13	.501	+ .197	64
20	.204	— .100	48	Mar. 5	.560	+ .256	42	26	.539	+ .235	59
Dec. 3	.232	— .072	18	17	.627	+ .323	37	July 12	.488	+ .184	75
11	.255	— .049	28	28	.464	+ .160	21	26	.430	+ .126	23
23	.302	— .002	43	April 9	.477	+ .173	37	Aug. 12	.506	+ .202	32
1894				19	.367	+ .063	33	Sept. 6	.549	+ .245	47
Jan. 2	.192	— .112	36	May 5	.513	+ .209	56	17	.295	— .009	28
11	.168	— .136	65	18	.532	+ .228	27	Oct. 2	.488	+ .184	45
23	.198	— .106	61	June 4	.551	+ .247	47	15	.490	+ .186	42
Feb. 2	.214	— .090	56	20	.554	+ .250	30	Nov. 1	.485	+ .181	59
12	.148	— .156	59	July 1	.501	+ .197	48	15	.354	+ .050	40
24	.193	— .111	86	12	.437	+ .133	31	Dec. 1	.251	— .053	48
Mar. 5	.234	— .070	68	31	.458	+ .154	47	14	.264	— .040	28
21	.083	— .221	51	Aug. 19	.379	+ .075	57	1899			
April 1	.192	— .112	33	Sept. 9	.331	+ .027	23	Jan. 14	.138	— .166	36
11	.199	— .105	65	26	.240	— .064	27	23	.291	— .013	44
23	.218	— .086	83	Oct. 13	.135	— .169	35	Feb. 3	.151	— .153	28
May 2	.153	— .151	89	25	.142	— .162	53	23	.146	— .158	35
12	.225	— .079	62	Nov. 10	.193	— .111	59	Mar. 13	.060	— .244	24
29	.216	— .088	50	23	.118	— .186	23	26	.955	— .249	16
June 8	.079	— .225	68	Dec. 5	.232	— .072	37	April 6	.189	— .115	28
17	.193	— .111	64	15	.314	+ .010	15	26	.366	+ .062	48
July 1	.114	— .190	34	28	.219	— .085	27	May 9	.275	— .029	29
16	.120	— .184	38	1897				14	.194	— .110	39
Nov. 15	.226	— .078	39	Jan. 8	.345	+ .041	23	29	.267	— .037	61
29	.274	— .030	43	25	.214	— .090	41	June 16	.459	+ .155	11
Dec. 18	.367	+ .063	25	Feb. 5	.387	+ .083	28	30	.275	— .029	46
1895				18	.362	+ .058	53	July 14	.309	+ .005	48
Jan. 2	.305	+ .001	20	28	.378	+ .074	55	25	.391	+ .087	21
15	.412	+ .108	53	Mar. 10	.452	+ .148	38	Aug. 12	.418	+ .114	51
Feb. 2	.380	+ .076	39	23	.283	— .021	10	22	.458	+ .154	42
14	.332	+ .028	40	April 25	.583	+ .279	41	Sept. 4	.322	+ .018	63
26	.425	+ .121	35	May 21	.565	+ .261	73	30	.397	+ .093	31
Mar. 10	.500	+ .196	18	June 1	.376	+ .072	16	Oct. 17	.451	+ .147	35
21	.346	+ .042	24	17	.573	+ .269	48	Nov. 5	.361	+ .057	51
April 8	.298	— .006	30	July 2	.595	+ .291	44	24	.369	+ .065	53
20	.353	+ .049	48	20	.597	+ .293	26				
May 7	.354	+ .050	44	Aug. 4	.522	+ .218	70	Mean	27.304		
18	.213	— .091	47								
June 4	.184	— .120	28	Aug. 22	.639	+ .335	44				
13	.257	— .047	51	Sept. 30	.503	+ .199	97				
July 5	.217	— .087	45	Oct. 16	.324	+ .020	13				
16	.286	— .018	23	Nov. 4	.361	+ .057	38				
28	.222	— .082	46	16	.254	— .050	20				

The record shows that observations were taken on 758 nights.

The four series of observations gave the following values of the Aberration Constant :¹

Series A.....	20."4566	Weight 18
B.....	20. 4525	" 16
C.....	20. 4695	" 26
D.....	20. 4704	" 27

Taking the probable error of a single latitude observation as 0".16 gives Constant of Aberration $20''.464 \pm 0''.006$.

Fergola obtained a value, corresponding in time to our Series A, of 20''.53, using the same stars and the same methods of reduction.

ON THE TEMPERATURE OF THE ACETYLENE FLAME.²

EDWARD L. NICHOLS.

(Abstract.)

These measurements were undertaken for the purpose of testing the truth of various statements concerning the temperature of the acetylene flame, made by Le Chatelier,³ Lewes⁴ and Smithells,⁵ and others. For this purpose, wires of pure platinum and of the platinum-rhodium alloy furnished by Hereaus in Hanau were drawn down to the following four sizes: (1) diameter, .01996 cm.; (2) diameter, .01598 cm.; (3) diameter, .01089 cm.; (4) diameter, .00821 cm. From these wires thermo-junctions were prepared, by bringing them into contact in the form of a V, fusing the apex, and trimming. These junctions were mounted upon a vertical support, the plane of the V being vertical and the line bisecting it at its apex horizontal. A flat luminous flame of acetylene was moved gradually towards the junction in such a position that the latter would enter its broader surface at the point of highest temperature. Readings of

¹The previous publications will be found in *The Astronomical Journal*, Nos. 401, 451, 474. In these papers the mean latitude is taken for each series and not, as in this case, for the whole time.

²Read at the meeting held on Feb. 24, 1900.

³Le Chatelier: *Comptes Rendus*, 121, p. 1144 (1895).

⁴Lewes: *Chemical News*, 71, p. 181 (1895).

⁵Smithells: *Journal of the Chemical Society*, 67, p. 434 (1895).

the electromotive force were taken, with the junction at various measured distances from the median plane of the flame, and curves were plotted showing the variations of temperature as indicated by the junction as a function of the distance of the latter from that plane.

From curves plotted in this manner and giving graphical representation of the temperatures indicated in various positions near the plane by each of the four thermo-junctions, it was possible to deduce a value for the temperature which would be indicated by a junction of zero cross-section when placed within the flame itself. This temperature was found to be 1920°C . For purposes of comparison the temperature of a luminous gas flame and of a candle flame were tested in like manner. The temperature of the luminous gas flame in the region corresponding to the brightest portion was found to be 1780°C ; that of the candle flame 1675°C . The temperatures assumed in computing the results of these measurements were those obtained by the use of a calibration curve upon which the melting point of pure platinum was taken at 1775° and that of gold at 1070°C .

This article is published in full in the *Physical Review*, Vol. 10, No. 4, p. 234.

THE USE OF THE CONDENSER AND BALLISTIC GALVANOMETER IN OBSERVATIONS OF ATMOSPHERIC ELECTRICITY.¹

F. L. TUFTS.

(Abstract.)

The Experiments described were conducted at Columbia University during the winter and spring of 1898-99 and were undertaken for the purpose of studying the behavior of a few different types of collectors of atmospheric electricity when used in connection with a condenser and ballistic galvanometer for measuring their potentials.

The Electrodes used were a flame, a water dropper, and a metal point electrode. They were supported about two meters from the

¹ Read at the meeting held on Feb. 24, 1900.

south wall of the laboratory building and about ten meters from the ground. The potentials of the electrodes were measured by connecting any one of them to one side of a condenser and grounding the other side. After the condenser had assumed the potential of the electrode it was discharged through a ballistic galvanometer of the D'Arsonval type provided with mirror telescope and scale.

It was very soon found that the current of electricity generated by even a good flame or water dropper electrode was so small that many seconds were required to charge a condenser of even a few hundredths of a microfarad capacity to the potential of the electrode. A condenser of one ten thousandth of a microfarad capacity, however, assumed the potential of the electrode within a second; that is, the potential readings were no higher when this condenser was left charging for three or four seconds than when discharged at the end of one second. A condenser of this capacity when charged to ten volts and discharged through the galvanometer gave a throw of one scale division. A throw of half a scale division could be easily read and potentials ranging from five volts to a few thousand volts either positive or negative could be readily measured in this way. In the work described below, the condenser of one ten thousandth of a microfarad capacity was used.

A series of readings of the potentials assumed by the flame, water dropper and metallic point electrodes were taken under different conditions of weather. It was found that the potentials indicated by the flame and water dropper were usually about the same. The metallic point always showed a much lower potential, usually less than five volts and very seldom over forty or fifty volts even when the flame or water dropper indicated a potential of several hundred volts. The potentials indicated by the electrodes seemed often to vary quite rapidly, so that if the potentials were read every half minute it was not uncommon to have successive readings differ by as much as fifty per cent. of the maximum. On other days a series of readings extending over five or ten minutes would show a variation of only a few per cent. of the maximum.

During the months of February and March, observations of atmospheric potentials were made every day by means of the flame and water dropper electrode, and the observations were continued, though with less regularity, up to the end of May. There seemed

to be indications of a daily maximum about four or five o'clock in the afternoon. A rapid increase in the atmospheric potentials generally preceded a storm. The potential readings were always positive except on the approach of a thunder storm, when they would often change quite rapidly from positive to negative. In one instant a change from plus three hundred volts to minus two hundred and eighty volts occurred within a half minute. Observations of the barometer, thermometer and hygrometer were carried on at the same time with the observations on atmospheric electricity, but no connecting relations were evident.

The method of the condenser and ballistic galvanometer, though not adapted for field work, affords a very simple and very convenient laboratory means of studying some of the phenomena of atmospheric electricity.

A NEW METHOD FOR THE CALIBRATION OF STANDARD RHEOSTATS.

H. C. PARKER.

(Abstract.)

It is often desirable to compare the coils of a standard rheostat directly against a standard ohm and so determine a table of corrections for the rheostat, or make certain that the coils are correct to within the errors of observation.

The Carey-Foster method by using the "commutator bridge" gives a most precise and satisfactory means for the comparison of standards of resistance of the same nominal value, but when rheostats in which the coils are arranged in sets of 1, 2, 3, 4, or 1, 2, 2, 5, are to be calibrated by comparing directly with a standard ohm the operation becomes extremely difficult. In fact, two rheostats have to be calibrated at the same time and the corresponding calculations are very involved.

The method known as "substitution in the bridge" (described in "A Systematic Treatise on Electrical Measurements") is perfectly adapted to the adjustment of the coils of a rheostat directly against a standard ohm, but requires the use of interpolation resistances and the observation of galvanometer deflections when a table of corrections is to be made out for a rheostat already adjusted.

The method devised by the writer, while based on this method, differs from it radically, it is a "zero" method, makes use of readings on the bridge wire in place of galvanometer deflections, and does away entirely with the interpolation resistances. It seems to possess all the advantages of the Carey-Foster method and the apparatus is much simpler, requiring only four mercury cups in place of the twenty mercury cups of the complicated commutator usually employed, at the same time it gives a very great range of measurement, since in place of actual differences in resistance it gives percentage readings.

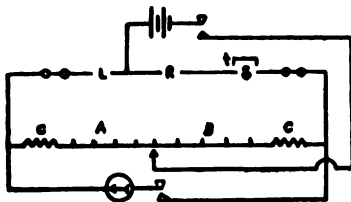
The arrangement of the apparatus, which may be called a "Percentage Bridge," is shown in FIG. 1.

The "percentage coils" cc are joined to the ends of the bridge wire AB . L represents an auxiliary rheostat which need only be approximately correct, R the rheostat to be calibrated, s a standard ohm and t a short circuit piece.

Let $L = 1$ ohm and $R = 1$ ohm,

Thence $C + A : C + B :: L : R$.

Suppose the resistance in one arm of the bridge is changed by amount θ and the corresponding displacement produced on the wire AB is λ , then $C + A - \lambda : C + B + \lambda :: L : R + \theta$.



Now when $\theta = .01$ ohm, (1 per cent. of 1 ohm) adjust the coils cc so that $\lambda = 100$ scale divisions, then 1 division = .01 per cent. (approximately).

If $L = 10$ ohms and $R = 10$ ohms, then when $\lambda = 100$ divisions, $\theta = .1$ ohm (1 per cent. of 10 ohms) and again 1 division = .01 per cent.

This being true for any values of L and R , the bridge when once adjusted to read in percentage will always indicate differences of resistance in percentage.

The resistance of the "percentage coils" cc for any given value of the wire AB can be calculated as follows:

Let $AB = 1$ ohm (1000 divisions), and the ratio of the change in resistance $= \frac{100}{K}$. Suppose the position of balance to be at the center of the bridge wire, then $A = B$, and $C + A = C + B = x$. Consequently $\frac{x - \lambda}{x + \lambda} = \frac{100}{K}$ and $x = \frac{\lambda(K + 100)}{K - 100}$. If $K = 101$ and $\lambda = 100$ divisions (.1 ohm),

$$x = \frac{.1(101 + 100)}{101 - 100} = 20.1 \text{ and } c = 20.1 - .5 = x - A = 19.6 \text{ ohms.}$$

That is in order to have 1 division displacement on the wire $AB = .01$ per cent. the ratio of the resistance of the wire AB to the coils cc must be as 1 : 19.6.

To find how nearly this ratio will give the true percentage for any other value of λ we may substitute in the equation $\frac{x - \lambda}{x + \lambda} = \frac{100}{K}$ and calculate the corresponding value for K , thus: if $\lambda = 1$ division (.001 ohm), $\frac{20.1 - .001}{20.1 + .001} = \frac{100}{K}$, $K = 100.00995$, and $100.01 - 100.00995 = .00005$, an error of only .00005 per cent. If $\lambda = 10$ divisions (.01 ohm), $K = 100.09955$, an error of only .00045 per cent.

These errors are, of course, quite beyond those of observation. Thus a bridge may be constructed on this principle that will read accurately in percentage from considerably above 1 per cent. to readings as low as .001 per cent.

By giving different values to λ and K , calculating the values of x from the equation $x = \frac{\lambda(K + 100)}{K - 100}$, and then substituting these values of x in the equation $\frac{x - \lambda}{x + \lambda} = \frac{100}{K}$, it is found that the best ratio of the bridge wire to the "percentage coils" is 1 : 19.6.

If the point of balance is not exactly at the centre of the bridge wire the error may be found as follows: suppose the point of balance to be 100 divisions ($\frac{1}{10}$ ohm) from the centre, then the proportion is 20.2 : 20.0 :: 1.01 : 1.00, and if $\lambda = 100$ divisions (.1 ohm) the proportion becomes 20.3 : 19.9 :: 1.0201 : 1.00. Now $1.0201 - 1.01 = .0101$, or an error of only .01 per cent.

An example will best illustrate the method of employing this bridge.

Rheostat No. 1 compared with Standard Ohm = 1.0005 true ohm @ 19°C.

Positions on bridge wire

Balance.	Substitution.	Difference in per cent.	Correct value.	No. of coil.
500	495	-.05	1.0000	1
426	435	+.09	2.0023	2

The apparatus is so easy to construct and adjust, being in fact only an ordinary bridge wire with the addition of the "percentage coils", that it seems possible it will be found useful in many electrical laboratories where the precise measurement of small differences in resistance or the comparison of resistance standards with the standard ohm is required.

THE ELECTRICAL RESISTANCE OF THIN FILMS DEPOSITED BY KATHODE DISCHARGE.¹

BY A. C. LONGDEN.

(Abstract.)

That there is a large field of usefulness for a thoroughly reliable high electrical resistance, no one doubts; but experience with high resistances of the inexpensive kind has been so generally unsatisfactory that we have almost come to look upon measurements which involve the use of a megohm or more as not much better than rough approximations.

Carbon resistances in general are unsatisfactory on account of their lack of constancy, and on account of the enormously high temperature coefficient of the material. The *only* advantage of carbon is its cheapness, and it *is* cheap in every sense of the word.

Alloys are preferred to pure metals in wire resistances because, in general, they have lower temperature coefficients and high specific resistance. Pure metals, however, are free from some of the objectionable features of alloys. The pure metals do not suffer from disintegration, and some of them are not affected by contact

¹Read at the meeting held on April 28, 1900.

with their surroundings. Now if it is possible to obtain a high resistance in the form of a pure metal and at the same time to retain all the advantages of an alloy, such a resistance ought to satisfy a long felt need. If in addition to this, the resistance is comparatively inexpensive, it certainly ought to come into pretty general use.

Miss Isabelle Stone¹ has shown that in thin silver films deposited upon glass from aqueous solutions, the ratio of the measured resistance to the calculated resistance is high,—in some cases, very high.

In the present investigation, work has been done on a great variety of thin metallic films deposited upon glass and other materials in vacua, by kathode discharge.²

The electrical properties of these films have been carefully studied, and they have been found similar to Miss Stone's silver films in the respect already mentioned; that is,—the thinner the film the higher is its specific resistance. It has also been conclusively demonstrated by this investigation that the temperature coefficient is a function of the thickness of the film; and that for films within a certain range of thicknesses, the temperature coefficients are approximately zero.

For platinum films about 5 cm. long and 15 mm. wide, the range within which negligible temperature coefficients occur is from a few thousand up to 100000 ohms resistance. For higher resistances, the temperature coefficients are pretty certain to be negative, and for *very* high resistances, that is, for very thin films, the negative temperature coefficients are usually quite large. Fortunately, however, it is not necessary to make a film exceedingly thin in order to produce a high resistance. A film having a resistance of, say 50000 ohms, and a zero or negligible temperature coefficient, may be cut into sections in such a way as to make the current travel the length of the film a large number of times. In this way the resistance of a film may be adjusted to a very high value without changing its temperature coefficient.

Another interesting fact in connection with these films is the

¹Physical Review Vol. 6. pp. 1-16.

²See Prof. A. W. Wright in *Am. Journal of Science and Arts*, Vol. 13, pp. 49-55 and Vol. 14, pp. 169-178.

peculiar relation which the temperature coefficient holds to the process of artificial aging. If the temperature coefficient is positive, the resistance undergoes a sudden and rapid increase when the film is placed in a hot paraffin or oil bath. A maximum is soon reached and then follows a gradual but long continued decrease. If, however, the temperature coefficient is negative, the resistance first falls and then gradually rises. Of course, if the temperature coefficient is zero, the resistance does not change, and in this case the film does not need much artificial aging.

After a suitable process of artificial aging, the films should be protected from the atmosphere. They may be sealed up in vacuum tubes or they may be simply imbedded in paraffin or coated with rubber cement.

There are several very good methods of making the electrical connections with these films. The most satisfactory method is to first deposit *thick* silver films of negligible resistance on the *ends* of the glass. These may be deposited from an aqueous solution by any of the well-known methods. A *thin* resistance film, as delicate as we please, may then be deposited over the entire surface of glass and silver. Fine copper wires may then be wound upon the thick silver ends, and lastly, the electrolytic deposition of copper or silver upon the joint makes the electrical contact perfect and permanent.

The method here described is capable of producing resistances of any desired value, from a few ohms up to several megohms. These resistances are not to be classed with carbon resistances, but may, if properly prepared, be regarded as perfectly trustworthy standards. They not only possess the permanence of pure metals, but they also possess the only desirable qualities of alloys, namely high resistance and low temperature coefficients.

During the progress of this investigation, Mr. C. C. Trowbridge of Columbia University requested me to deposit a selenium conducting film for him. The attempt was unsuccessful, because the selenium always comes down in the amorphous form, which does not conduct electricity. While at work on selenium, however, a very interesting phenomenon was observed. On account of the form and size of the kathode, the film was somewhat uneven in thickness; and, as the material is transparent enough to transmit large quanti-

ties of light through films several wave lengths in thickness, the beams of light reflected to the eye from the two surfaces of the uneven film, produced interference fringes. By re-arranging the kathode, it was found possible to produce films having uniformly convex upper surfaces, so that circular interference fringes similar to Newton's Rings were obtained. These rings, however, are characterized by great brilliancy and unusual size. They are especially well adapted to lantern projection.

AN ELEMENTARY METHOD OF INTEGRATING CERTAIN LINEAR DIFFERENTIAL EQUATIONS.¹

R. S. WOODWARD.

(Abstract.)

The following differential equations are of frequent occurrence in mechanics and mathematical physics.

$$\frac{dx}{dt} + ay = 0, \quad \frac{dy}{dt} - ax = 0, \quad (1)$$

and

$$\frac{d^2x}{dt^2} + 2n \frac{dx}{dt} + a^2x = 0, \quad (2)$$

where a and n are constants. The integrals of (1) are well known to be

$$x = a \cos (at + \theta), \quad y = a \sin (at + \theta), \quad (3)$$

where a and θ are constants. The integral of (2) is well known to take different forms according as $n^2 > a^2$, $n^2 = a^2$, or $n^2 < a^2$. Equation (2) represents the phenomena of damped vibrations. When $n = 0$, it represents simple harmonic motion in a straight line; while equations (1) represent the rectangular components of uniform motion in a circle. The usual methods of integrating these equations require some knowledge of the theory of differential equations in general. It is the object of Professor Woodward's paper to show how to integrate them without the aid of such knowledge. To this end, observe that (1) and (2) are comprised in the following equations of the first order :

¹ Read at the meeting held on April 28, 1900.

$$\frac{dx}{dt} + ay + 2nx = 0, \quad \frac{dy}{dt} - ax = 0. \quad (4)$$

These equations give

$$\frac{dx}{2nx + ay} = -\frac{dy}{ax} = -dt,$$

whence, by the introduction of two factors β, γ ,

$$\frac{\beta dx}{2nx + ay} = -\frac{\beta \gamma dy}{a \gamma x} = -\beta dt,$$

or
$$\frac{\beta dx - \beta \gamma dy}{(2n + a\gamma)x + ay} = -\beta dt. \quad (5)$$

The first member of this equation will be an exact differential if

$$\beta = 2n + a\gamma, \text{ and } -\beta\gamma = a, \quad (6)$$

whence

$$a\gamma = -n \pm \sqrt{n^2 - a^2}.$$

Thus the two values of β derived from (6) are

$$\beta_1 = n + \sqrt{n^2 - a^2}, \quad \beta_2 = n - \sqrt{n^2 - a^2} \quad (7)$$

Writing $\omega^2 = n^2 - a^2$, it is seen that

$$\begin{aligned} \beta_1 &= n + \omega, & \beta_2 &= n - \omega, & (n^2 > a^2); \\ \beta_1 &= n, & \beta_2 &= n, & (n^2 = a^2); \\ \beta_1 &= n + i\omega, & \beta_2 &= n - i\omega, & (n^2 < a^2). \end{aligned} \quad (8)$$

Introducing β_1 and β_2 in (4), and observing the second of (6), there result

$$\frac{\beta_1 dx + ay}{\beta_1 x + ay} = -\beta_1 dt, \quad \frac{\beta_2 dx + ay}{\beta_2 x + ay} = -\beta_2 dt.$$

Integrating these and calling the values of x and y for $t = \tau$, x_0 and y_0 respectively,

$$\begin{aligned} \beta_1 x + ay &= (\beta_1 x_0 + ay_0)e^{-\beta_1 \tau}, \\ \beta_2 x + ay &= (\beta_2 x_0 + ay_0)e^{-\beta_2 \tau}, \end{aligned}$$

whence by elimination

$$\begin{aligned} (\beta_2 - \beta_1)x &= (\beta_2 x_0 + ay_0)e^{-\beta_2 \tau} - (\beta_1 x_0 + ay_0)e^{-\beta_1 \tau}, \\ a(\beta_2 - \beta_1)y &= (\beta_1 \beta_2 x_0 + a\beta_2 y_0)(e^{-\beta_1 \tau} - e^{-\beta_2 \tau}) - (\beta_1 \beta_2 x_0 + a\beta_1 y_0)(e^{-\beta_2 \tau} - e^{-\beta_1 \tau}). \end{aligned} \quad (9)$$

Substituting in these the first pair of values from (8), there result

$$\begin{aligned} x &= e^{-nt} \left(x_0 \cosh \omega t - \frac{nx_0 + ay_0}{\omega} \sinh \omega t \right), \\ y &= e^{-nt} \left(y_0 \cosh \omega t + \frac{ax_0 + ny_0}{\omega} \sinh \omega t \right), \end{aligned} \quad (10)$$

($n^2 > a^2$).

Similarly, using in (9) the last pair of values in (8), or replacing ω in (10) by $i\omega$,

$$\begin{aligned} x &= e^{-nt} \left(x_0 \cos \omega t - \frac{nx_0 + ay_0}{\omega} \sin \omega t \right), \\ y &= e^{-nt} \left(y_0 \cos \omega t + \frac{ax_0 + ny_0}{\omega} \sin \omega t \right), \end{aligned} \quad (n^2 < a^2). \quad (11)$$

For the intermediate case in which $n^2 = a^2$, or $\omega = 0$, it is seen at once from (10) or (11) that

$$\begin{aligned} x &= e^{-nt} \{x_0 - a(x_0 + y_0)t\}, \\ y &= e^{-nt} \{y_0 + a(x_0 + y_0)t\}, \end{aligned} \quad (n^2 = a^2). \quad (12)$$

For the special case in which $n = 0$, and hence $\omega = a$, or for the case of simple harmonic motion specified by (1), (11) give

$$x = x_0 \cos at - y_0 \sin at, \quad y = y_0 \cos at + x_0 \sin at,$$

which become identical with (3) by means of the substitution $x_0 = a \cos \theta$, $y_0 = a \sin \theta$.

SOME NOVEL EXPERIMENTS IN STATIONARY SOUND WAVES.¹

BERGEN DAVIS.

(Abstract.)

1st. The first experiment was a variation of the well known Kundt dust figures. Instead of cork dust I used gelatine capsules such as are used for medical purposes. They are very light and expose a large surface to the streamline action. A large number of capsules were put at random in the middle of the loop of the first overtone of an organ pipe. When the pipe gave a very loud tone, the capsules arranged themselves in rows across the pipe. There was strong attraction at the ends of the capsules and a repulsion at the sides. Each capsule attached itself to the end of its neighbor. The spacing between the rows varied from 3 cm. to 5 cm. The smallest sized capsules obtainable were used in this experiment.

2nd. The Sound Wave Anemometer. While studying the Kundt figures, it occurred to me that the air particles must have an appreciable amplitude in order to produce the effect observed. To test this a small anemometer was constructed. The cups were half cylinders formed by cutting No. 2, gelatine capsules into two parts longitudinally. These half-cylinders were placed on the ends of card-board arms with a glass pivot at the centre. The anemometer thus formed was mounted on the point of a fine needle. The diameter of the semi-cylindrical cups was .572 cm. The length of each cup was 1.5 cm.

The organ pipe had a glass side to render the interior of the pipe visible. A stopped pipe was used and it was blown with sufficient force to give a strong overtone. This gave a node at the stopped end and another at a point about one-third of the distance from the mouth-piece to the end. Near this node a thin rubber diaphragm was placed across the pipe, thus converting that part of the pipe between the node and the stopped end into a closed chamber, which was kept free from currents that might arise from blowing the pipe.

¹ Read at the meeting held on April 28, 1900.

A diaphragm near a node does not alter the intensity of the sound appreciably. The anemometer when placed in the middle of the loop rotated with a high velocity. The rate of revolution varied with the position in the stationary wave. It came nearly to rest at the nodes. The rates of revolutions when plotted as ordinates with the distances along the pipe as abscissae gave approximately a sine curve. If the law of the anemometer, that the velocity of the cups is one-third of that of the moving air, holds in vibratory motion, then it is possible to determine the average velocity of the air particles and hence their amplitude. A few experiments with this object in view gave an amplitude of 3.2 mm. at the middle of the loop.

3rd. A New Effect Produced by Stationary Sound Waves. While experimenting with the Kundt figures, as shown by the capsules previously mentioned, the following effect was obtained: The cap was removed from one of the capsules, and it thus formed a small cylinder closed at one end. This cylinder arranged itself perpendicularly to the length of the pipe and also *moved* across the stream lines in the direction of the closed end. The force producing this motion was of considerable magnitude. So far as I am aware this effect has not been before observed. I have investigated this effect in the stationary wave produced by the first overtone of an organ pipe. The pipe used was the one described above. It was 70 cm. long and the interior cross-section was 5 cm. by 6.35 cm.

A small mill was made by fastening four cylinders, closed at one end, at the ends of card-board arms. This mill was mounted, by means of a glass pivot, on the point of a fine needle. The needle was fastened in the end of a glass rod which was destined to carry the mill to any desired part of the wave. A manometer was used to obtain a constant force of blowing the pipe. The pipe was placed vertically with the stopped end downwards, and the glass rod bearing the mill was introduced from below. The plane of the mill was perpendicular to the direction of motion of the vibrating air particles. The maximum rate obtained was 9 per second at the loop. The mill came to rest at the nodes. The rates of revolution when plotted as ordinates with distance along pipe as abscissae gave almost a sine curve.

The force acting on the closed end of the cylinder was measured

by means of a torsion balance. The torsion wire was carried through the wall of the pipe by means of a glass tube. The torsion wire was of No. 035 phosphar-bronze about 8 inches long. There was a graduated circle at the top of the glass tube. The pipe was so arranged that measurements could be made in any part of the stationary wave. Two cylinders, each 7.57 mm. in diameter and 31 mm. in length, were mounted on the end of the torsion arm. They were made from No. 00 gelatine capsules.

The same force of air blast was maintained throughout a series of experiments. The maximum torsional deflection obtained at the middle of the loop was 600° . The deflection was zero at the nodes. A curve was plotted with the *square roots* of the deflections as ordinates. The curve approximated a sine curve.

The portion of the pipe between the diaphragm and the stopped end formed a closed chamber. Into this chamber I introduced various gases and determined the corresponding torsional deflection. Experiments were made as to the torsional force at the middle of the loop in air, carbon-dioxide, illuminating gas and hydrogen. Care was taken to blow the pipe with the same force throughout the experiments. The mean results are given in the table below. The force in air is taken as unity and a comparison is made between the deflections and the densities of the gases :

	Torsion force.	Density.
Air	1	1
C O ₂	1.47	1.53
Illuminating gas77	.75
Hydrogen064	.069

The agreement is striking and suggests a possible method of determining molecular weights of permanent gases.

The rate of revolution of the mill above described was next taken. The measurements were made only at the middle of the loop. The rate in air is taken as unity.

Air.	Illum. Gas.	C O ₂ .	Hydrogen.
1	1	1.04	.59

It will be observed that for the first three gases, the rate is constant although the forces at the ends of the cylinders producing this rotation is proportional to the density.

This result may be explained by the circumstance that the resistance to its motion that the mill experiences is also proportional to the density of the gas.

Prof. Wm. Hallock suggested to me the explanation of this effect. He pointed out that Bernoulli has shown that a fluid in motion is less dense than the same fluid at rest.

The air within the cylinder is at rest, while that without is in motion. The result is a force acting on the closed end of the cylinder due to the difference in density.

The difference of density obtained by experiments gave a force of 21 dynes per sq. cm. of area. I have used this method also to obtain the velocity and amplitude of the air particles at the middle of the loop.

Prof. R. S. Woodward has kindly assisted me in applying the proper hydrodynamical equations to the solution of the problem. For this case since the average state of the fluid only is under consideration Bernoulli's equation applies, *i. e.*,

$$\int \frac{dp}{\rho} = R - \frac{1}{2} u^2$$

R is the potential due to external forces and is negligible in this case.

The adiabatic law gives $p v^\gamma = C$, C is the gas constant.

$$\text{Therefore } A \left(P_1^{\frac{\gamma-1}{\gamma}} - P_2^{\frac{\gamma-1}{\gamma}} \right) = \frac{1}{2} (u_2^2 - u_1^2)$$

$$\text{where } A = \frac{\gamma}{\gamma-1} C^{\frac{1}{\gamma}}.$$

Let u_2 be the velocity in a region without the cylinder near the closed end. Let u_1 be the velocity in a region inside the cylinder next to the closed end. If the air within the cylinder is at rest $u_1 = 0$.

$$A \left(P_1^{\frac{\gamma-1}{\gamma}} - P_2^{\frac{\gamma-1}{\gamma}} \right) = \frac{1}{2} u_2^2.$$

$$u^2 = 2 A n \frac{p_1 - p_2}{p_1}, \quad n = \frac{\gamma-1}{\gamma}$$

$$u^2 = 2 \left(\frac{C}{p_1} \right)^{\frac{1}{\gamma}} (p_1 - p_2).$$

The quantity $(p_1 - p_2)$ was that measured by the torsion balance.

The results obtained gave an amplitude of 3.27 mm. This agrees well with the value found by the sound wave anemometer.

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FALSE SPECTRA FROM THE ROWLAND CONCAVE GRATING.¹

THEODORE LYMAN.

(Abstract.)

It is proposed to show that among the spectra formed by the Rowland Concave gratings there are spectra not accounted for by the ordinary theory of the grating ; that such spectra are common and at times fairly strong and of excellent definition ; that these spectra are diffraction spectra, of much less dispersion than the ordinarily recognized spectra, and that the errors of ruling to which they are due are not local but general to the whole surface of the grating. Finally it is proposed to explain an experimental method by which these false lines can be sorted out from the regular and calculable overlapping spectra. These spectra are especially dangerous in series spectra work, giving a somewhat systematic reproduction of strong lines and groups, which reproductions in actual vibration frequencies do not exist. There is probability and some evidence that such errors have been committed in the past, and it was in the presence of this danger that the false spectra were discovered.

SOME PRELIMINARY EXPERIMENTS UPON THE EFFICIENCY OF THE ACETYLENE FLAME AS A SOURCE OF LIGHT.²

E. L. NICHOLS.

(Abstract.)

Investigations are in progress under the direction of the author, by means of which it will be possible to determine the percentage of light-producing energy obtained by the combustion of acetylene. For this purpose it is proposed to explore the visible and invisible

¹ Read at the meeting held on June 28, 1900.

² Read at the meeting held on June 26, 1900.

spectrum of the flame of that gas, and to measure the relation of the non-luminous to the luminous energy. By means of these measurements, taken together with redeterminations of the heat of combustion of acetylene gas and of the proportion of the total energy developed by the flame which is given out in the form of radiation, the factors of the problem of the efficiency of this source of light will be fully determined. In the meantime, owing to the general interest in acetylene as an illuminant, it has been deemed worth while to report the results of certain measurements already completed. In these preliminary experiments the determination of the relation of luminous to non-luminous energy has been made by the well known approximate method of Melloni, in which the deflection of a galvanometer in circuit with a thermopile, exposed at a fixed distance from flame, is compared with the deflection of the same instrument, when a glass cell containing water is interposed, and when a water cell and also a cell containing an opaque solution of iodine in carbon disulphide are interposed in the path of the rays. Measurements of this description completed under the direction of the author of this paper by Messrs. Stewart and Hoxie gave for the radiant efficiency of the acetylene flame 10.5 per cent., a value which is in good agreement with the radiant efficiency of other illuminants, as determined by earlier investigators.

Determinations of the heat of combustion of acetylene gas obtained by the ordinary methods of generation from calcium carbide and without any attempt at purification, made by means of the Fabre and Silbermann calorimeter, gave values for various samples averaging about ten thousand calories. The relation of this value to the theoretical value of the heat of combustion (12200.) is about what might be expected with the gas in question, since analyses of gas similarly generated from the same stock of carbide have shown a percentage to pure acetylene running from seventy-five to eighty per cent. These experiments were performed by Mr. H. A. Rands.

The preliminary work to determine what part of the total heat developed in the flame is given off in radiation, has been performed by Mr. Albert Ball, using gas from the same generator as that tested by Mr. Rands. The method which I proposed to Mr. Ball for this purpose is a modification of that previously employed by

Julius Thomsen¹ and by Rogers². It consists in exposing a thermopile to radiation from a spherical flask of hot water, and subsequently under similar conditions to the radiation from the flame to be studied. The surface of the flask was carefully blackened and water was maintained at constant temperature by means of a coil of wire electrically heated. The total amount of energy imparted to this coil was determined by measurement of the current and electromotive force, and the heat lost by convection was estimated by placing the flask alternately in still air and in vacuo.

Mr. Ball's measurements showed the proportion of radiant energy to total energy to depend upon the pressure at which gas was supplied to the acetylene flame, the ratio diminishing as the pressure increased. This ratio, under normal conditions of composition, was found to be approximately 20 per cent., and from this value, taken together with Mr. Rand's direct determination of the heat of combustion of the gas consumed, and the determinations of Stewart and Hoxie, already referred to, for the radiant efficiency, it appears that the total efficiency of the luminous acetylene flame is about 2.1 per cent. (0.021).

The total efficiencies of various candles, oil flames, and gas flames, have been estimated to lie between 0.002 and 0.003. Rogers, in his study of the magnesium flame, found the total efficiency to be 10 per cent. The superiority of burning magnesium over the acetylene flame and all other gas flames, lies in the fact that the product of the reaction is a solid (MgO) so that comparatively little heat is carried away by convection; about 25 per cent. as against 80 per cent. for acetylene.

By *total efficiency*, as used in this communication, is meant the ratio of the light giving energy to the total energy developed in the flame. The term *radiant efficiency* is used to denote the ratio of the light giving energy to the total radiation from the flame.

Physical Laboratory of Cornell University,

June 15, 1900.

¹ Julius Thomsen, Poggendorff's Annalen, Vol. 125, p. 348.

² Rogers, American Journal of Science, Vol. 43, p. 301 (1892).

ON THE POLARIZATION OF THE CORONA.¹

N. ERNEST DORSEY.

(Abstract.)

The corona was photographed through a double-image prism, thus giving two images polarized at right angles to one another; the polarization of the corona is plainly seen in this way. We also photographed the coronal spectrum through a large double-image prism. The exposure was too short to bring out the bright lines, but the continuous spectrum shows the polarization very plainly. The polarization is undoubtedly radial and is quite strong. Eye observations were also made to obtain some idea of the percentage of light polarized and how this varied along the radius, and also along a circle concentric with the sun. It appeared to be approximately the same along the circumference, and to increase as the distance from the sun increases. No absolute value can be given, as the instrument has not yet been standardized.

A COMPARISON OF THE BRIGHTNESS OF PRISM AND GRATING SPECTRA.²

(Abstract.)

N. ERNEST DORSEY.

A prism and a grating spectroscope were adjusted so as to view the same source of light, which was focused by lenses on the slits of the two instruments. The slit of the prism instrument was set at a known width, and the other slit was adjusted until the intensities of the two spectra were estimated to be equal at some given portion of the spectrum. Then, assuming that the intensity of the spectrum is proportional to the width of the slit, we can (after correcting for the difference in size of the collimators and for the magnifying power) obtain a measure of the relative intensities of corresponding

¹ Read at the meeting held on June 28, 1900.

² Read at the meeting held on June 28, 1900.

parts of the spectrum, as given by this grating and by this prism train when used under identical conditions. The results thus obtained indicated that the first spectrum of a very ordinary plane grating, giving three usable spectra on each side, is in the red 4, in the yellow 5, in the green 6, and in the blue 8 times as bright as that given by the prism train. The prism spectroscopy was a Grubb two-story instrument with an effective train of ten, four and a half centimeter, sixty degree prisms having a refractive index at D of about 1.6. These numbers are only intended as rough approximations, but they are the averages of several settings and are probably correct to about 10%. The error mentioned by Mr. Brace at the December meeting is probably not very great here, as the slits were never wider than 0.3 mm.

Johns Hopkins University,
June, 1900.

THE ANOMALOUS DISPERSION OF CYANIN.¹

(Abstract.)

R. W. WOOD AND C. E. MAGNUSSON.

The dispersion of solid cyanin has been investigated both by means of the spectrometer and the Michelson interferometer.

Prisms of solid cyanin, made by the method described by one of the present writers (*Phil. Mag.*, XLVI, 380,) by pressing the fused dye between plates of glass, were investigated with the spectrometer, both within and without the region of strongest absorption, and the dispersion curve found to be continuous. The ultra violet part of the spectrum was investigated by photography, the method employed by Pflüger being used. Over eighty determinations were made (each one being the mean of several settings of the spectrometer) and the results plotted on coördinate paper. A second absorption band was found in the ultra violet beginning at wave length .00037.

A similar curve was obtained with the interferometer, the displacement of the fringes by a thin film of cyanin being determined.

¹ The paper will appear in full in the Proceedings of the London Physical Society, and the *Philosophical Magazine*.

The fringes were photographed in monochromatic light, of various wave lengths, obtained by prismatic dispersion, and the displacement measured on the photographic plates. The curves obtained by the two methods were shown. The absorption band in the ultra violet was found in the interferometer work also. Pflüger found no trace of this band, and gives several readings within it.

The photographs taken with the interferometer enable us to show by means of a lantern that the dispersion curve is in reality unbroken. No application of the results to the dispersion formulae can be made until more information about the ultra violet absorption band has been obtained.

THE OPTICAL PROPERTIES OF THIN CARBON FILMS.¹

(Abstract.)

R. W. WOOD.

It was suggested to me by Professor Ames that the rapid decrease in amplitude of the wave front from the refracting edge of prisms, made of strongly absorbing media, such as cyanine, might have some influence on the direction of the ray after leaving the prism. In other words, might shift slightly the position of the effective point on the wave front, as determined by Huygens's principle. In searching for some method by which a rapid decrease of amplitude could be obtained without any retardation, I was led to try the effect of thin films of carbon, made by depositing smoke on glass by means of a gas flame. As the carbon particles are just barely visible under a 1-12 inch oil immersion objective, it seemed possible that the light might be cut off without introducing a retardation. Examination of the films with an interferometer showed a very marked retardation, however. On looking over the literature on the subject, I found that this fact had been already noted by Rosicky, and also by Stark, who made the assumption that the case is that of a turbid medium, namely air of low refractive index, and carbon particles of high refractive index. It seemed to me not unthinkable that the retardation might, in this case, be due to diffraction. The particles are

¹ Read at the meeting held on June 26, 1900. Paper will appear in full in *Proceedings of the London Physical Society*, and *Philosophical Magazine*.

small in comparison with the light waves, and the ratio of the space occupied by carbon to that occupied by air is as $2\frac{1}{2}$ is to $97\frac{1}{2}$, according to Stark's determination.

If the waves were obliged to pass around the particles, a retardation would be introduced owing to the increase in the optical path. This retardation by diffraction was found in the case of sound by photographing a wave after it had passed between three layers of glass tubes, arranged above one another with spaces between the adjacent tubes.

It seemed likely that an examination of the dispersion of such a film might give some clue to the cause of the retardation. If it was the result of diffraction we should expect either a complete absence of dispersion, or a greater retardation for the red than the blue.

The results obtained with the interferometer showed that the retardation was greater for the long than the short waves. Similar experiments were made with a carbon film obtained by sealing up a piece of plate glass in an incandescent lamp, and running the lamp for some hours considerably above its normal voltage. Films obtained in this way give regular reflection at normal incidence, for violet light. The particles, therefore, must have a diameter less than $\frac{1}{8}$ of the wave length of violet light, otherwise there would be introduced phase discrepancies of more than $\frac{1}{4}$ of a wave length, which is the maximum allowable if the wave is to be propagated undisturbed. The thickness of this film was measured with the interferometer and the refractive index, as calculated from this value and the retardation of Sodium light, was found to be 2.2.

To corroborate the results obtained with the interferometer smoke prisms were made, and an examination with the spectrometer showed that the image of the slit was deviated more when illuminated with red light than when illuminated with blue. The retardation at the base of the prism was then measured with the interferometer. It was found to be nearly two wave lengths for Sodium light. The width of the prism was then measured and the angular deviation calculated. The value obtained agreed very closely with the spectrometer measurements. The analogy between the dispersion curve of smoke films and the dispersion curve within the absorption band of substances exhibiting anomalous dispersion is perhaps suggestive.

A MICA ECHELON GRATING.¹

(Abstract.)

R. W. WOOD.

It occurred to me that an echelon grating of very thin plates, yielding spectra in which the distance between two close would be less than the distance between the spectra would be useful in illustrating the subject to classes. It is impossible to grind glass plates sufficiently accurate less than a couple of millimeters thick. I accordingly tried thin mica, selecting a film giving uniform retardation when examined with the interferometer, cut it into small pieces and built up an echelon which gave very satisfactory results. The thickness of the mica was found to be .05 mm., the retardation about 50 waves, consequently we have to deal with spectra of about the fiftieth order. The grating consisted of eight elements, consequently the resolving power was about 400. This was insufficient to resolve the sodium lines, but the two yellow mercury lines were divided with ease. A grating was ruled in a smoke film with the same spacing and number of lines. This barely separated the red from the violet in the first order. The mica echelon separated lines distant from one another about two times the distance between the sodium lines.

For the yellow Hg lines $\frac{\delta\lambda}{\lambda} = 280$.

The formula expressing the ratio between the distance between two lines and the distance between two adjacent spectra is

$$\frac{\delta\theta}{\delta\theta_1} = \frac{t}{\lambda} \frac{\delta\lambda}{\lambda}$$

For the Hg lines and the mica echelon we have

$$t = .05$$

$$\frac{t}{\lambda} = 94 \qquad \frac{\delta\lambda}{\lambda} = 290.$$

$$\therefore \delta\theta = \delta\theta_1 \frac{94}{280} = \frac{1}{3}$$

or the distance between the lines is $\frac{1}{3}$ of the distance between adjacent spectra, which was found to be the case.

¹ Read at the meeting held on June 26, 1900.

ELECTRIC ABSORPTION IN CONDENSERS.¹

L. M. POTTS.

In this paper a description of the method used in the study of electric absorption was given. The effect of *E.M.F.* period of current and temperature is discussed. The variation of the capacity with change of period of the measuring current is also discussed.

SPARK-LENGTH AS MODIFIED BY SOLID DIELECTRICS.²

W. J. HUMPHREYS.

(Abstract.)

The spark-length between oppositely charged electrodes, those of an ordinary electric influence machine for instance, may be greatly increased by bringing a glass rod or other solid dielectric near that side of the positive pole that faces the cathode. In any other position the effect of the glass rod is negligibly small.

One of the most interesting of the many tested modifications of this experiment, is that of two leyden jars oppositely charged, and well insulated from each other. In this case the discharge between the inner coatings is evidently started in some way by disturbances due to the solid dielectric and not by oscillations.

The phenomenon seems to be due to the relatively high specific inductive capacity of the solid dielectric, and if so, suggests the following hypothesis.

The dielectric between two poles is most sensitive to electrical disturbances at points next the anode. This also accords with Faraday's experiments on dischargess between sphere of unequal size, and explains why when a spark is set up by oscillations it appears only when the surge is in the direction *anode to cathode* (see Spark-Length, etc., *Physical Review*, May-June, 1900).

¹ A brief report of the work appeared in J. H. V. circulars for June, 1899, and June, 1900. A full account of the work will appear in *American Journal of Science*.

² Read at the meeting held on June 28, 1900.

The peculiar sensitiveness of the anode, while not yet accounted for, may be due to the clustering of different types of ions about the two poles or to the different sizes and velocities of the two classes of ions themselves.

SOME SIMPLE APPARATUS FOR THE STUDY OF AERIAL VIBRATIONS.¹

(Abstract.)

F. L. TUFTS.

One of the pieces of apparatus for the measurement of the relative intensities of aerial vibrations is acted upon by the changes in density accompanying such vibrations, and consists of an ordinary globular shaped resonator having a very thin rubber membrane tied over its open end. To the center of the membrane, and perpendicular to it, is attached a small rectangular piece of tin foil, having a narrow slit cut in it near its outer edge parallel to the plane of the membrane. The amplitude of vibration of the membrane can be measured by means of a microscope, provided with a micrometer ocular, which is focussed on the slit in the tin foil index. The slit is illuminated by an incandescent lamp. The lamp, microscope, and resonator are all mounted on a suitable support so that the whole forms a single piece of apparatus which is very portable and not likely to be thrown out of adjustment.

Another piece of apparatus for the purpose of indicating the direction and relative amplitudes of vibration of the air particles, consists of a thin rubber membrane, tin foil index, microscope, and lamp, as is the preceding piece. The membrane, however, instead of closing the mouth of a resonator is stretched upon a brass ring, and is thus not set in vibration by the changes in density of the air but only by the to and fro motion of its particles. In order to indicate the direction of motion of the air particles, the membrane is mounted so that it can be revolved upon either one of two mutually perpendicular axes, the center of the membrane being at the point of intersection of the two axes produced. The plane of the membrane can

¹ Read at the meeting held on June 28, 1900.

thus be given any desired position, and the amplitude of vibration of the membrane in that position will be proportional to the component of the aerial vibration in a direction perpendicular to the plane of the membrane. The amplitude of vibration of the membrane is measured, as in the preceding piece of apparatus, by measuring the width of the band of light formed by the vibration of the illuminated slit in the tin foil index attached to the center of the membrane. The membrane, microscope, and lamp are suitably mounted upon a single support so that they can be easily carried from place to place without being thrown out of adjustment.

In using the above described apparatus for the study of sound waves, I have employed as the source of sound a closed organ pipe blown by a steady current of air. The end of the pipe was closed by a sliding piston so that the effective length could be varied and thus the fundamental note of the pipe brought in unison with that of the resonator or membrane. The periods most frequently used were from one to two hundred vibrations per second, and the membranes employed ranged from two to four centimeters in diameter. With the microscope used an amplitude of about .006 mm. was as small as could be readily measured. Among the various uses to which the apparatus can be put may be mentioned the following :

Both pieces of apparatus described have been used to verify the law of the inverse squares as applied to the radiation of sound from an organ pipe. The maximum distance from the pipe at which observations were made was about twenty-five meters. With the second piece of apparatus described, the direction of vibration of the air particles, and consequently the position of the wave front, has been determined.

The latter piece of apparatus has also been used in studying the direction of vibration of the particles in the stationary waves set up by a pipe when made to speak in a closed room.

Both pieces of apparatus have been used in comparing the intensities of sound after transmission through various porous materials, and thus the relative opacity of such materials to sound determined.

If the pipe is blown so that its overtones become rather pronounced, the second piece of apparatus can be used to show some of the peculiarities of the resultant vibration due to the combination of the overtones with the fundamental.

ON THE CHARACTERISTIC EQUATION OF WATER.¹

(Abstract.)

A. D. RISTEEN.

The relation between the pressure, absolute temperature and volume of a gas may be quite accurately represented by an equation of the form

$$p = tf(v) - F(v), \quad (1)$$

as has been shown by Amagat, Ramsay and Young, and others. The physical fact underlying this formula appears to be that the potential energy of the molecules of the gas depends only upon the volume, while the kinetic energy depends only upon the temperature. There are no evident reasons why this same physical fact might not be true in liquids also; but it appears to be impossible to find an equation of the type (1) which will represent Amagat's measures upon water satisfactorily, and hence we must infer that the molecular potential energy of water is not a function of the volume alone. The most satisfactory form that I have been able to obtain, thus far, for the characteristic equation of water, is

$$p = \frac{\alpha(t)}{v - \lambda} - \beta(t), \quad (2)$$

where

$$\alpha(t) = 1,363.1 + 3.126t - \frac{36,292}{t - 210^{\circ}},$$

and

$$\beta(t) = 14,870.3 - 14,565t - \frac{479,360}{t - 182^{\circ}}.$$

t being the absolute temperature on the centigrade scale, and p being estimated in atmospheres. The unit of volume is the volume occupied by water at the freezing point, under a pressure of one atmosphere, and $\lambda = 0.7085$. Equation (2) agrees very closely with Amagat's experiments, over the entire range of pressure and temperature; that is, from 1 to 1000 atmospheres, and from 0° C. to 100° C.

¹ Read at the meeting held on June 28, 1900.

MAGNETIC OBSERVATIONS ON THE DAY OF ECLIPSE,
MAY 28, 1900.¹

(Abstract.)

L. A. BAUER.

Simultaneous readings of the magnetic declination were made under my direction by observers of the Coast and Geodetic Survey at six stations—three situated inside the belt of totality and three outside, covering an area from Alabama to Maryland. The readings were taken from 7 A. M. to 4 P. M., 75th meridian time, at intervals of one minute from 7 to 11 A. M., and thereafter every five minutes, the temperatures also being read. Moreover, at the principal station, Rocky Mount, North Carolina, in center of belt of totality, in addition to making declinometer readings under the tent, Eschenhagen variation magnetometers (declination and horizontal intensity) were installed in a tobacco barn, and eye-readings were taken with both instruments during same intervals as for the other stations, and besides every fifteen seconds for five minutes about time of totality. Ten observers were engaged in this work, and eight complete series of observation were obtained—seven for declination and one for horizontal intensity. *All of the stations show a magnetic effect, which cannot be referred to any other cause than that of the eclipse, the principal effect occurring, like the fall in temperature, some minutes after time of totality.* The effect is as though part of the night hours were interposed among the day hours, *e. g.*, the declination at all of the stations having passed the morning elongation and approaching the mean value of day, is *increased* about 20" —40", if the declination be east; and *decreased* if the declination be west; whereas, the horizontal intensity approaching at the time its minimum value for the day, is *increased* for a brief period after time of totality. The observations and results will be published in full in a Bulletin of the Coast and Geodetic Survey.

¹ Read at the meeting held on June 28, 1900.

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J. S. AMES

M. I. PUPIN

ERNEST MERRITT

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The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

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THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Seventh Meeting.

A regular meeting was held in Fayerweather Hall, Columbia University, New York City, on Saturday, October 27, 1900, at 11 o'clock.

In the absence of the President and Vice-President, Mr. Magie was elected temporary chairman. The following papers were presented :

1. A new form of experimental organ pipe for studying some phenomena of stationary sound waves. By F. L. Tufts.
2. Note on the influence of a magnetic field upon the "Edison Effect." By Ernest Merritt.
3. Note on the Faraday Effect. By D. B. Brace.
4. The resistance of the air at speeds below 1,000 feet a second. By A. F. Zahm.

Minutes of the Eighth Meeting.

The regular annual meeting was held in Fayerweather Hall, Columbia University, New York City, on Thursday, Dec. 27, 1900.

President Rowland called the meeting to order and asked the Treasurer to act as Secretary. The minutes of the meeting of October 27th, 1900, were read and approved.

The President then appointed E. F. Nichols and A. L. Kimbal as tellers, to canvass the vote for officers for the year 1901. They reported a total of 74 votes cast: H. A. Rowland, 73 for president; A. A. Michelson, 73 for vice-president; Ernest Merritt, 74 for secretary; W. Hallock, 74 for treasurer; Henry Crew, E. B. Rosa, 74 for councillors; and these persons were declared elected.

The following papers were read :

On anomalous propagation of electric waves. M. I. Pupin.

A search for a new source of electromotive force. H. A. Rowland.

Theory of magnetò-optics. H. A. Rowland.

On the heat of Arcturus, Vega, Jupiter and Saturn. Ernest F. Nichols.

On cyanine prisms and a new method of exhibiting anomalous dispersion. R. W. Wood.

On the propagation of cusped waves and their relation to the primary and secondary focal lines. R. W. Wood.

A brief account of the Paris congress of physicists. A. G. Webster.

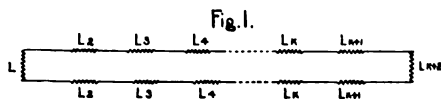
Adjourned at 4 P. M., 31 present.

WAVE PROPAGATION OVER NON-UNIFORM ELECTRICAL CONDUCTORS.*

M. I. PUPIN, PH.D.

INTRODUCTION.

The main object of the mathematical theory developed in this paper is the analysis of the propagation of electrical waves over a conductor represented in Fig. 1. This conductor consists of a loop of wire $L_1 \dots L_n$ of length $2l$ in which there are at equidistant points, the so-called reactance points, certain number of equal coils



interposed dividing the loop into a number of equal parts, called the interstices of the loop. These coils may have condensers in series with them or they may have secondary circuits with condensers. The propagation of electrical waves over a periodically loaded loop of this kind is compared to that over a uniform loop having the same total inductance, resistance, and capacity. This uniform loop is called "*the corresponding uniform conductor*" of the periodically loaded loop.

*Presented at the meeting held on Dec. 28, 1899.

A similar problem in Mechanics is that of forced and of free vibrations of a periodically loaded heavy, flexible, intensible string of finite length taking frictional resistance into account. To my knowledge, neither the electrical problem nor its corresponding mechanical problem have been investigated before.

It will be observed in the course of this paper that a study of the propagation of electrical waves over a periodically loaded conductor of this kind suggests forcibly an electromagnetic theory of emission and absorption of light by molecular complexes, which on account of the physical conception underlying it, if for no other reason, possesses many attractive features. In this theory the ether and the material ions imbedded in it correspond to the uniform wire and the reactance points considered in this paper. These matters, however, are of a more or less speculative character and have, therefore, no place here. But it should be confessed that the physical problem discussed here was first suggested by speculations of this kind. The problem of this paper is a definite engineering problem and can be stated as follows:—Under what conditions will the non-uniform conductor represented in Fig. 3 be approximately equivalent to its corresponding uniform conductor? Or, to be more precise: For what frequency will an electrical wave have approximately the same wave length and the same damping or attenuation constant on one conductor as on the other?

The mathematical theory developed here gives a definite answer to this question. This answer can be stated in a few words and for that purpose it is desirable to introduce here a new technical term, the so-called *angular distance* of the interstices,—that is, of the intervals between consecutive reactance points. This interval is at any given frequency a definite fraction of the wave length corresponding to that frequency. Instead of measuring it in terms of the wave length it is convenient to measure it in terms of an angle. If we assign an angle 2π to the wave-length under consideration and an angle ϕ to the distance between two consecutive reactance points such that ϕ is the same fraction of 2π as this distance is of the wave length then ϕ is the angular distance of the interstices of the loop. The general rule expressing the conditions of equivalence of a non-uniform conductor to its corresponding uniform conductor can then be expressed as follows:—For any given frequency

a non-uniform conductor of the second type is equivalent to its corresponding uniform conductor as nearly as the sine of half the angular distance of its interstices is equal to half this angular distance itself.

The higher the frequency the less resemblance will there be between a given non-uniform conductor and its corresponding uniform conductor. Conversely, if this resemblance is sufficiently close for a given frequency it will be closer for all lower frequencies. When the half wave-length under consideration becomes smaller than the interstices then the resemblance as far as that wave length and all shorter wave lengths are concerned ceases altogether.

The physical significance of this rule will be stated now. All progressive electrical waves are gradually attenuated as they advance along their path of propagation. This is true of Hertzian waves along conducting wires, as well as of the longer electrical waves employed in telegraphy and telephony. This attenuation is, of course, due to dissipation of the wave-energy produced by imperfect conduction. In a long sub-marine cable, for instance, this attenuation is so rapid that the wave-energy put in at one end is almost entirely dissipated before it reaches the other end of the cable. The greater the inductance of the conductor, other things being the same, the smaller will be the attenuation. Few physical facts can be made more evident than this, and yet there is hardly any other relation in mathematical physics the physical meaning of which is so little understood as the physical meaning of this relation between attenuation and inductance. A few words on this point will not be out of place here. Propagation of wave-energy is due to the successive transformations of this energy from the kinetic form to the potential and vice versa. Thus in the case of electrical waves the wave energy oscillates between the electrokinetic or magnetic form and the electro-potential form. The first one resides in the magnetic field which accompanies the current, the second resides in the electrical field the tubes of induction which terminate on the surface of the wire. But whenever the wave energy passes through its electrokinetic or magnetic form the electrical current accompanying it brings with it dissipation on account of imperfect conduction. This dissipation will be the greater the greater the current which accompanies a given amount of electrokinetic energy. By increas-

ing the inductance we can reduce this current to anything we please and, therefore, reduce the dissipation to any limit. By reducing the dissipation the attenuation is reduced. A conductor of high inductance increases, therefore, the efficiency of transmission of wave energy very much, and for that reason the problem of constructing such a conductor is worthy of the best efforts of the physicist and the engineer. But there seemed to be no way of increasing the inductance of a uniform conducting wire beyond certain small limits, particularly in cables where such an increase is especially desirable on account of the large electrostatic capacity of the cable. The physical significance of the rule given above, which is the culminating point of the mathematical theory developed in this paper, can now be easily seen. Since for a given frequency and therefore for all frequencies lower than this one a non-uniform conductor of the second type can be made equivalent to its corresponding uniform conductor, and since the inductance of such a non-uniform conductor can be varied within very wide limits, it follows that a non-uniform conductor of the second type represents a new method of constructing an electrical conductor which will afford a high degree of efficiency of transmission.

A numerical example is given in Sect. III which tests the practicability of this method. The author has been engaged for some time now in experimental researches of this matter. The results so far obtained confirm the theory quite satisfactorily. A part of these researches was published last spring,¹ the rest will be published in the near future.

¹ Pupin, M. I.—Propagation of Long Electrical Waves; Transactions of the American Institute of Electrical Engineers, Vol. XV, 1899.

REPORT ON THE SPECIFIC HEATS OF NON-ELECTROLYTES IN SOLUTION.¹

WILLIAM FRANCIS MAGIE.

The present report describes the continuation of the research published in the *Physical Review*, Vol. IX, No. 2, August, 1899. It is concerned, 1, with the improvement of the calorimetric method employed; 2, with the molecular heats of certain isomers discharged in water; 3, with the variable molecular heat of milk sugar dissolved in water.

1. The calorimeter described in the article referred to has been modified by using covered vessels and rotating paddles as stirrers, thus checking irregular evaporation. Tests with water and with solution show that individual results in a series of observations differ from the mean by not more than $\frac{2}{100}$ of one per cent.

2. To test how the water of crystallization is to be reckoned in when a solution is made, a solution of dextrose containing water of crystallization was examined. The solution was made up to contain 1 gram molecule of dextrose to 250 gram-molecules of water on the supposition that the water of crystallization leaves the crystal on solution and becomes a part of the solvent. The molecular heat obtained for the dextrose was 78.9, in exact agreement with the mean molecular heat previously obtained for dextrose without water of crystallization. This result justifies the assumption on which the solution was made up. The molecular heats of the isomers cane sugar, milk sugar, and maltose are as follows:

Cane sugar	152.8
Milk sugar	145.
Maltose	145.

The molecular heats of the isomers mannite and dulcite are as follows:

Mannite	108.6
Dulcite	95.

¹ Presented at the meeting held on Feb. 24, 1900.

Evidently the molecular heats of the isomers are not the same, and so depend upon differences of structure and not solely upon atomic composition. This conclusion is supported by an examination of the molecular heats obtained for organic compounds. It is found impossible to assign fixed atomic heats to their constituents from which the molecular heats of the compounds can be obtained as additive quantities.

3. An examination of a solution of milk sugar, in which 1 gram molecule of milk sugar was dissolved in 200 gram molecules of water showed an apparent variability in the molecular heat. As a mean of three sets of observations, the molecular heats taken at about 25-minute intervals are 147, 138, 144, 147, 149, 151, 153, 150. After the lapse of a day or two the molecular heat was 145, and showed no further variations. With a more dilute solution the value 155 was obtained at once. Boiling did not destroy the variability with the more concentrated solution. In all cases the value obtained after the lapse of a day or two was 145.

A variability of the rotary power of milk sugar solutions for polarized light has been shown by Erdmann and by Schmacger, and is ascribed by them to the gradual formation of an allotropic modification of the milk sugar in the solution. In view of the fact that no perceptible temperature changes accompany this modification, and that the departures of the observed molecular heats are both in defect and in excess of the final constant value, it seems probable that the observed variations are real and due to modifications of molecular structure.

Princeton University, February, 1900.

A METHOD OF OBTAINING BRILLIANCY OF CONCAVE-GRAFTING SPECTRA.¹

BY W. J. HUMPHREYS.

The chief obstacle to the use of the concave grating in the analysis of faint lights is the feebleness of the spectral lines it gives. This of course is due to a variety of causes, such as multiple spectra, stigmatism, absorption, etc. But the results obtained with a good concave grating are so excellent that one naturally wishes to use it whenever it is possible. Any device therefore that extends its field, or shortens the time of photographic exposure must be a desirable thing.

To this end the following is suggested. Let the sources of light be such that its image, formed on the slit, shall be at most one millimeter long. Such a source is an electric spark between suitable terminals in the air, or an end on vacuum tube. For convenience we may regard this image as a point. The light from this image passes on in a cone to the grating, and usually—that is for most positions of the grating—covers a considerably larger surface than the grating space.

Now place a pair of optical flats 1" x 5" say between the slit and grating, but within very few inches of the slit, and let them be so adjusted that they are symmetrically placed with reference to the line joining the center of image on slit and center of grating, and further so that the line of intersection of the two reflecting planes shall be perpendicular to the plane of slit and a grating line. Suitable inclination and spacing of the mirrors will now cause much of the light that went on either side of the grating space, and was therefore lost, to be reflected back on to the ruled surface. In this way we have one real and two virtual sources of light, but they are on the slit and therefore, owing to the stigmatism of the concave grating give superimposed and thus intensified spectra.

¹ Presented at the meeting held on June 29, 1900.

ON DOUBLE MAGNETIC REFRACTION.¹

BY D. B. BRACE.

The explanation of the Faraday "effect" by Fresnel's interpretation and experimental verification in the case of quartz has so far been without experimental confirmation. Righi, Becquerel, Cornu and the writer have shown the relative acceleration and retardation of two opposite circular components in a magnetic field by means of the displacement of interference bands. The same has also been observed for elliptically polarized light by the writer, the effect, however, gradually being obliterated in the bands as the ellipticity increased. This, however, only demonstrates the effect of a field on polarized light and does not determine the actual mode of propagation in the medium. Other plausible theories assume a direct rotation of the vector without resolution. Direct refraction must be resorted to. However the change in index would be very small — carbon bisulphide giving only one one-hundredths that of quartz in a field of 10,000 *C.G.S.* units. In the case of quartz, Fresnel found no difficulty in obtaining a refracting surface with a combination of right and left-handed specimens. No such combinations are known in magnetic substances. Special methods in refraction must be resorted to. The methods tried by the writer previously in connection with the experiment mentioned above by interference were ineffectual.

The fortunate idea, however, of combining two rectangular prisms so that a ray might be totally reflected successively along and then at right angles to the lines of force together with a separating retardation plate to maintain the proper circular polarization has rendered the experiment finally possible. The prisms were of the heaviest glass, $n_D = 1.903$. The two diagonal faces were separated by a plate of mica cemented together by α — monobromonaphthalin, thus forming a rectangular parallelepiped whose internal diagonal face was 2 in. by 4 in. high. This was placed with the diagonal face parallel to the lines of force. Two small rectangular

¹ Presented at the meeting held on Oct. 27, 1900.

prisms cemented respectively to the top and the bottom of the adjacent rectangular faces allowed a ray of light from a slit to pass into the system at right angles to the mica and the lines of force and be totally reflected parallel to the same and again reflected at right angles to the field and the mica, and so on around five times—a total of twenty reflections—and thence out to the observing telescope through the second laterally cemented rectangular prism mentioned above. When the ray first enters the prism there will be no magnetic action since the Faraday "effect" is zero at right angles to the lines of force; but on reflection will break up into two opposite circular components having different velocities and hence directions of propagation, if we use Fresnel's method of interpretation; but not if we assume merely rotation of the vector. At the second reflection these circular vibrations become elliptical, due to total reflection, and they must be so changed that after the third reflection each is still circular and has the same absolute direction of vibration as after the first reflection. In this way the deviations at each successive reflection will add together. Such a deviation could either be produced by a change in velocity or by a change in phase or by both, since the disturbance at any point is the integral of that from all the elementary Huyghenian zones of the wave-front. We can not then by this method determine as to velocity or change of phase.

To find the deviation of each reflection we have

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_r} \quad \text{or} \quad \delta r = \frac{\sin i}{\cos r} \frac{\delta v_r}{v_1}$$

We have also

$$\frac{\delta v_r}{v_1} = \frac{\delta s}{s} = \frac{\theta}{\pi} = \frac{\lambda r}{s} = \frac{\theta}{\pi} \frac{\lambda}{n}$$

where θ is the rotation through a distance s and λ the wave length in air and n the refractive index. If $\theta = \omega H$, where ω is Verdet's constant, we have

$$\delta r = \omega H \frac{\lambda}{n} \frac{\tan i}{\pi}$$

In the experiment

$$i = 45^\circ \quad H = 8700 \quad \omega = 0.1 \quad \lambda_D = 6 \times 10^{-5} \text{ approx. and } n_D = 1.903.$$

Hence

$$\delta r = \frac{0.1 \times 87 \times 10^2 \times 6 \times 10^{-5} \times 1}{1.9 \times 3.14} = .0087' = .52'' \text{ approx.}$$

For twenty reflections $\delta r = .52'' \times 20 = 10''.4$.

A double slit whose elements were 0.5 m.m. apart, was placed at a distance of 10 meters from the prism through which the slit could be examined by the observing telescope. The absolute angle subtended becomes $.5/10000 = .0005$, while $10''.4$ reduces, in absolute units, to $.000048 \times 10''.4 = .0005$ approximately.

The prism was placed so that it could not be strained in any way by pressure from pole pieces. These latter were reduced from a circular section of 8 in. diameter, to a section 4 in. square. The prism could also be tilted so as to obtain a different number of complete passages within it. The oxyhydrogen jet playing on sticks of fused salt was used to obtain sufficient intensity of light.

On closing the circuit, the two images in the telescope field changed into three, the central band being apparently equal in intensity to the sum of the other two. On examining with a Nichol prism the outer bands were found to be plane polarized at right angles to each other and at 45° to the plane of reflection or horizontal plane. When a single slit was used the image became double, each element being plane polarized at right angles to the other and 45° to the horizontal plane. When the field was reversed the polarization of the images was interchanged. The rays must therefore have been circularly polarized since the last reflection and final passage through the mica plate and the reflection at the interface of the auxiliary and rectangular prisms change the phase by an amount between a quarter and three-eighths of a period, thus giving approximately plane polarized light. On looking into the telescope with the lines of force passing from right to left, the image appearing on the right would be seen thus as right-handed or rotating in the direction of the hands of a watch and the image on the left, left-handed. This requires that the vibrations in the direction of the Amperian currents have the greater velocity of propagation and those opposite, a velocity as much less than the normal velocity. It must consequently result that light can only be transmitted by circular vibrations along the lines of force.

A NEW CHRONOGRAPH FOR MEASURING SMALL INTERVALS OF TIME.¹

BY ALBERT F. ZAHM.

For more than a century experiments have been made, from time to time, to determine accurately the resistance of the air at all speeds from zero to the highest attainable. The result seems to prove that the resistance varies as the square of the velocity at speeds below one to two hundred feet a second and above thirteen to fourteen hundred feet a second. For intermediate velocities there has been much divergence of opinion among the various investigators, due mainly to the inaccuracy of the chronographs employed. A new instrument of fairly general use, but particularly designed for measurements in gunnery, is described in this paper.

The main principle of all modern ballistic measurements is the same. The projectile's time of transit is recorded for three or more equi-distant points along the horizontal part of its path. These times serve to compute the velocity, acceleration and resistance of the projectile. Usually electric screens are fixed at the several points of the trajectory, and the instant of their rupture recorded by some form of electric chronograph. The best of such instruments, hitherto employed in resistance determinations, have measured time accurately to about one ten-thousandth of a second. The chronograph here described measures accurately to much less than one hundred-thousandth of a second, and the accelerations determined by it are quite uniform.

In passing, it may be said that to insure the best results all records were taken indoors in homogeneous still air. Moreover, the projectiles were of wood, some solid, others hollow, and weighing $\frac{1}{20}$ to $\frac{1}{40}$ as much as steel ones, thus making the acceleration 20 to 40 times as great and precisely measurable. In addition the ballistic screens were beams of light $\frac{1}{100}$ of an inch thick which offered no resistance, and could be ruptured in a millionth of a second by a

¹ Presented at the meeting held on Oct. 27, 1900.

bullet of moderate speed ; whereas with electric wire screens the wire stretches before rupture, and its ends remain in close contact with the projectile for some time after its mechanical severance.

Fig. 1 shows the application of the chronograph to ballistic measurements. The gun is at *G*, and in front of it are eight smoke screens for stopping the blast when the gun is fired. The ball, emerging from the screens passes through still air cutting three sunbeams, and lodges in a box of cotton. The beams, springing from the mirrors *MMM*, pass through the slits *AAA*, *BBB*, and are reflected from the right angle prisms *RRR*, to a camera where they come to focus on a photographic plate *P*. When the gun is fired the plate falls, and the sunbeams trace on it three fine, straight lines close together, each being momentarily interrupted when its tracing sunbeam is cut by the bullet. The positions of these three interruptions serve to calculate the bullet's velocity and resistance.

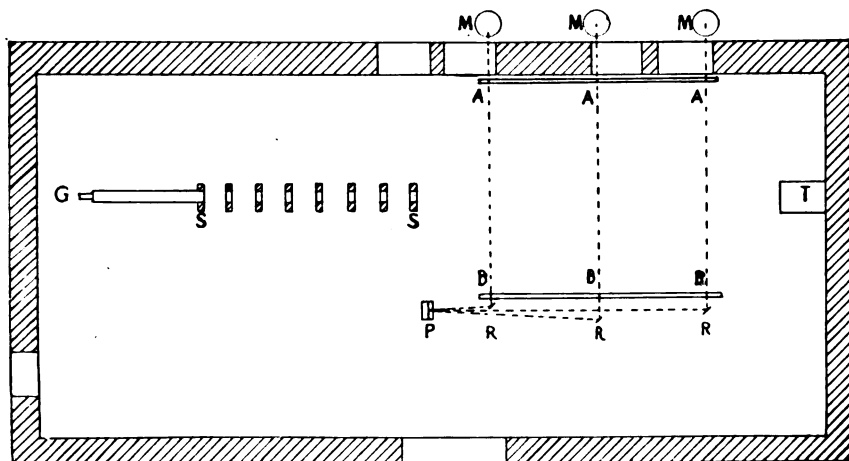


Fig. 1.—Application of the Chronograph in Exterior Ballistics.

The gun is a four-inch brass pipe seven feet long with a toy cannon screwed into its breech for an explosion chamber, and using smokeless powder. The bullets thus far used are polished wooden spheres. The light beams are seven feet apart, the spacing being effected by two iron slit bars on either side of the trajectory.

The camera, Fig. 2, is a columnar cast-iron box, 5 feet high, three by five inches inside section, and provided with two interior side

grooves, down which a massive iron bar drops freely, carrying with it a photographic plate, 2 feet high by $2\frac{1}{2}$ inches wide. At the bottom of the camera is a cushion which yields to the impact of the falling mass so as not to endanger the plate; and in the back of the

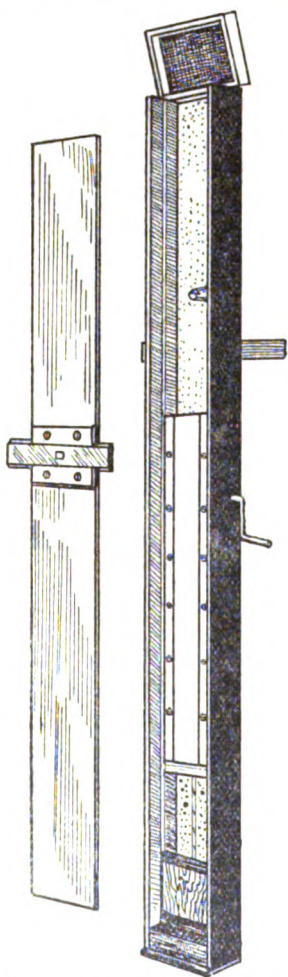


Fig. 2.—The Camera with its Front Removed.

camera is a windlass which draws the plate and holder up to their initial position where they are held on a firm latch ready for another drop. After each fall of the plate the camera may be displaced sideways, say $\frac{3}{16}$ of an inch, while the shutter and lens remain stationary; thus it is possible to take a dozen or more records on one plate. Outside and back of the camera is a trigger whose mechanism drops the plate, opens the shutter, and fires the gun at preadjusted time intervals.

The records are measured on a dividing engine, and, when due care is taken, reveal the bullet's velocity accurately to one-twentieth of one per cent.; its acceleration, and hence resistance, accurately to about one per cent. Doubtless the same accuracy is attainable in interior ballistic measurements. If a pole, pierced at three points is centered in the nose of the projectile, and run through a guide at the gun's muzzle, a single beam of light shining through the pole will give a record having three interruptions which will reveal the velocity and acceleration of the pole.

The chronograph has been used to determine the resistance of the air at speeds below 1000 feet a second. The data obtained verify, as far as they go, the law of Col. Duchemin, maintained by him on analytical grounds in the early part of this century, but controverted

by the most accurate ballistic researches of the past sixty years. Duchemin's law is expressed by the equation $R = av + bv^2$, for speeds below 1366 feet a second, and by the equation $R \propto v^2$, for higher speeds, R being the resistance, v the velocity of the projectile, and a , b , constants. I hope to have other records taken to test Duchemin's law at speeds above one thousand feet a second.

It would be interesting to determine the possible accuracy of a chronograph of this kind. By increasing the speed of the plate and intensity of the light I have reason to believe that the records could be made to reveal time intervals of one hundred millionth of a second.

*Department of Mechanics,
The Catholic University of America.*

ON THE HEAT OF ARCTURUS, VEGA, JUPITER AND SATURN.¹

E. F. NICHOLS.

(Abstract.)

The paper described measurements made at the Yerkes Observatory during the months of August, 1898 and 1900.

The apparatus used consisted of a 36 x 30 inch plane mirror heliostat used to direct the star heat to a 24 inch concave mirror of 7 ft. 9 in. focal length, in the principal focus of which stood one vane of a very sensitive radiometer. The radiometer was the same in principle and construction as one earlier described² except that the sensitive vanes, which were circular and of 2 mms. diameter, were smaller, and the whole suspension lighter than in the previous instrument. The star rays entered the radiometer through a fluorite window 3.4 mms. thick.

In the summer of 1898 measurements were made on Arcturus and Vega, and in 1900 on Arcturus, Jupiter and Saturn. The series obtained were averaged and reduced to a mean sensitiveness for the

¹ Presented at the meeting held on Dec. 27, 1900.

² *Phys. Rev.* Vol. 4, p. 298.

radiometer, and by the aid of Müller's extinction coefficients¹ the observed intensity for each body was reduced to its zenith intensity for comparison. The values were finally expressed in terms of a unit equal to the one-hundred-millionth part of the radiant heat from a candle at a distance of a meter. This unit has for convenience been called 10^{-8} meter-candle. The results of the measurements on the bodies in question are expressed below in terms of this unit.

Vega,	0.5
Arcturus,	1.1
Jupiter,	2.4
Saturn	0.37

There is very little reason to doubt the genuineness of the heat effects observed although the measurements are at best but roughly quantitative.

The sensitiveness of the apparatus used including the radiometer and the increased aperture of the mirror is roughly 26 times as great as that of the 16 inch mirror and radiomicrometer used by Boys² should correspond in a similar investigation in 1888-1889.

Full details of the experiments will appear in the March number of the *Astrophysical Journal* for 1901.

¹ Müller, *Photometrie der Gestirne*, Leipzig, 1897.

² C. V. Boys. *Proc. Roy. Soc.* 1890, p. 480.

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BOARD OF EDITORS

J. S. AMES

M. I. PUPIN

ERNEST MERRITT

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The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

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THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Ninth Meeting.

A regular meeting of the Society was held in Fayerweather Hall, Columbia University, New York City, on Saturday, February 23d, 1901.

In the absence of the President and Vice-president, Mr. Hallock was made temporary chairman.

The following papers were presented :—

1. Wattmeter methods of measuring the power dissipated in condensers. E. B. Rosa.
2. The relative efficiency of an organ pipe when blown at different pressures. F. L. Tufts.
3. The freezing points of aqueous solutions of non-electrolytes. E. H. Loomis.
4. Anomalous dispersion of sodium vapor. R. W. Wood.
5. Formula for freezing point depression. W. F. Magie.

Minutes of the Tenth Meeting.

A regular meeting of the Society was held in Fayerweather Hall, Columbia University, on Saturday, April 27, 1901, at 11 o'clock.

In the absence of the Vice-president, Mr. Hallock was made temporary chairman.

The secretary announced that the vacancy in the office of President of the Society, caused by the death of Henry A. Rowland, had been filled by the Council by the election of Albert A. Michelson as President for the remainder of the unexpired term. It was further announced that, to fill the vacancy thus caused in the office of Vice-president, Arthur G. Webster had been elected by the council as Vice-president of the Society for the remainder of the unexpired term.

The following resolution, presented by a committee of the Council, was adopted :

The Physical Society desires to record its deep sense of sorrow for the death of its late President, Professor H. A. Rowland, and its appreciation of his services to science. By his brilliant researches he did much to advance our knowledge of physics, and by his work as a professor he stimulated many students to greater zeal for accurate scholarship and scientific investigation. His interest in the Society was shown from its beginning and it owes much to the care with which he watched over its organization. By his death the Society, the science which it represents, and our own country have sustained a loss which will be severely felt.

It was ordered that the resolution be incorporated in the minutes, that it be printed in the Bulletin, and that a copy be sent to the family of Professor Rowland.

It was announced that the Society would hold a joint meeting with Section B of the American Association for the Advancement of Science at Denver during the coming summer, and that all arrangements regarding the joint meeting had been placed in the hands of a committee consisting of D. B. Brace, chairman, E. L. Nichols and William Hallock.

The following papers were presented :

1. A new phenomenon produced by stationary sound waves. Bergen Davis.
2. The National Bureau of Standards. S. W. Stratton.
3. The counter electromotive force of the electric arc. H. J. Hotchkiss.
4. Experimental demonstration of the path of the invariable axis in a Poinso't motion. A. G. Webster.
5. Quantitative experiments with a top. A. G. Webster.
6. The efficiency of the acetylene flame. E. L. Nichols.
7. The specific heat of electrolytes in solution. W. F. Magie.
8. The elastic properties of helical springs. J. W. Miller. Introduced by R. S. Woodward.

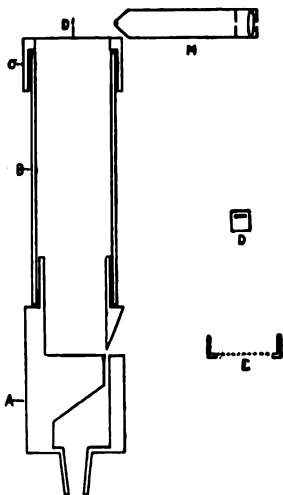
A NEW FORM OF EXPERIMENTAL PIPE FOR STUDYING SOME PHENOMENA OF STATIONARY SOUND WAVES.¹

F. L. TUFTS.

(Abstract.)

The apparatus was devised for the purpose of studying the phenomena of the transmission of the energy of stationary sound waves through various porous materials which are introduced as obstructions at different positions with reference to the nodes of such waves. It has also been useful in studying certain phenomena connected with organ pipes.

A vertical cross section of the apparatus is shown schematically in Fig. 1. It consists of a cylindrical organ pipe having its mouth piece, *A*, detachable and the pipe tube, *B*, provided at its upper end with a cap, *C*, over the end of which is stretched a thin rubber membrane. A rectangular piece of tin foil, *D*, having a narrow slit cut in it near its upper end is cemented to the center of the membrane.



A microscope, *M*, provided with some form of micrometer ocular is mounted so that it can be focused on the slit in *D*, which is illuminated by a lamp not shown in the cut. When the pipe speaks, the vibrations of the membrane cause the narrow slit of light seen in the microscope to broaden into a band the width of which can be measured by the ocular scale and the amplitude of vibration of the membrane can be thus determined. A shallow cylindrical tray, *E*, provided with a bottom of wire gauze fits snugly in the pipe tube, *B*, and can be slid to any desired position in the tube. In finding the resistances offered by different porous materials to the transmission of sound the materials under investigation were placed in this tray

¹ Presented at the meeting held on Oct. 27, 1900.

and located at various positions with respect to the node of the stationary wave in the tube.

The pipe was made to speak by connecting it to a source of compressed air and some form of manometer connected to the compressed air pipe at its junction with the organ pipe indicated the pressure at which the pipe was blown, a suitable stop cock inserted somewhere between the air reservoir and the manometer connection enabled me to control the pressure. To determine the rate at which energy was supplied to the pipe a gas meter was inserted between the stop cock and the mouth of the pipe so that all of the air delivered had to pass through the meter. The rate of flow of air through the mouth of the pipe could thus be readily determined, and the cube of this velocity is theoretically proportional to the rate at which energy is being delivered to the pipe.

In constructing the pipe the tension of the membrane over the cap, *C*, should be such that the fundamental note of the membrane will be as high or higher than the note emitted by the pipe, thus preventing the membrane from dividing into nodes and loops. Under this condition if the pipe is made to speak its first overtone, for example, at different pressures the amplitude of vibration of the index attached to the membrane will be proportional to the amplitude of the air particles in the pipe and the energy of the first overtone in the pipe will be proportional to the square of the amplitude. When such a pipe speaks its first overtone the position of the node is readily located by finding experimentally the length of a stopped pipe, of the same form and diameter as the experimental pipe, which is in unison with the overtone.

The preliminary experiments with the pipe were for the purpose of finding the relation between the rate at which energy is supplied to the pipe and the energy in the predominant note. The pipe was made to speak its first overtone at various pressures differing by a half centimeter of water column. For each different pressure the amplitude of vibration of the membrane was read and also the rate at which air was being supplied to the pipe. The results were plotted on cross-section paper, the points located having ordinates proportional to the cubes of the velocities of flow of air through the mouth of the pipe and abscissae proportional to the squares of the corresponding amplitudes of the membrane. These points

were connected by a smooth curve. An examination of a number of curves obtained in this manner showed that for any given pipe there was a limited range of pressures for which the energy of the predominant note was approximately proportional to the rate of supply of energy to the pipe and that as the pressure was either increased or decreased beyond these limits the energy in the predominant note increased less rapidly or decreased more rapidly than the rate of supply of energy to the pipe.

The same data were also plotted using pressures as ordinates and amplitudes as abscissae. The curves obtained were of the same general character as the energy curves and the range of pressures at which the amplitudes were approximately proportional to the pressures was the same as the range of pressures at which the energy of the predominant note was proportional to the rate of supply of energy to the pipe. The pressure at which the amplitude and energy of the predominant note vary at the same rate respectively as the pressure and rate of supply of energy to the pipe, I will call the pressure of maximum efficiency for the pipe. It is the pressure at which, for that particular pipe, the maximum per cent. of the energy supplied is converted into sound of the predominant note of the pipe.

In studying the resistance offered by different porous materials to the transmissions of the energy of the stationary wave, the tray (E, Fig. 1,) containing the material would be placed in the pipe at various distances from the node. For each position of the tray the pipe was made to speak its first overtone at different pressures, the amplitude of vibration of the membrane at each pressure being read off in the microscope. The amplitudes corresponding to the respective pressures of maximum efficiency for the different positions of the tray in the pipe were the ones used in calculating relative resistances. The investigations are still in progress. For porous materials of a granular nature, however, the following conclusions seem warranted by the results so far obtained.

For a given granular material the resistance offered to the to and fro motion of the air particles in a stationary sound wave is proportional to the thickness of the material, and this is true whether the material is near a node or a loop of the stationary wave.

The relative resistances of different granular materials vary according to the distance from the node at which the comparisons are made. For example, if a given thickness of a certain material, *A*, offered twice as much resistance as the same thickness of another material *B*, when the comparison was made near a node it would offer more than twice, perhaps ten times the resistance of *B* if the comparison were made near a loop of the stationary wave.

The materials so far investigated were composed of spherical granules which for a given material were of a uniform size. In most cases the granules consisted of ordinary lead shot.

NOTE ON THE INFLUENCE OF A MAGNETIC FIELD ON THE EDISON EFFECT.¹

BY ERNEST MERRITT.

If an incandescent lamp contains a third terminal insulated from the filament, it is found that a current of several milliamperes may be obtained by connecting this terminal or electrode, through a galvanometer, with the negative terminal of the lamp. If connection is made between the electrode and the positive terminal no current, or an extremely small one, is obtained. This phenomenon, often called the Edison Effect, has been made the subject of several extended investigations. There can be no doubt that it is closely related to the numerous other cases of undirected conductivity of gases, produced by incandescent bodies, which have been studied by Elster and Geitel and others.

It has been shown, both by Elster and Geitel and by Fleming, that the current in such cases is diminished by a magnetic field whose direction is at right angles to the current. This effect was explained by Elster and Geitel on the assumption that the current is carried by charged particles or ions, which were deflected when passing through a magnetic field. Recent experiments of J. J. Thomson in the main confirm this view. It now appears probable that negative corpuscles similar to those constituting the cathode rays, are formed at the incandescent surface, and that there act as the carriers

¹ Presented at the meeting held on Oct. 27, 1900.

of current in the case of the Edison effect and similar phenomena. It seems reasonable to expect also that these corpuscles may ionize the gas through which they pass, as in the case of the cathode rays. If this is true the phenomena must be complicated by Electrolytic conduction in the gas surrounding the incandescent body ; and it is only at low pressures, *e. g.*, in the bulb of an incandescent lamp, that the phenomena appear in their simplest form.

A quantitative study of the effect of a magnetic field in deflecting the corpuscles would require somewhat elaborate apparatus. But to show the effect qualitatively seems to present no great difficulties. An incandescent lamp containing a third terminal between the two straight portions of an ordinary U-shaped filament has been found quite satisfactory for this purpose. Lamps of this kind were at one time on the market, the third terminal serving some purpose connected with the process of manufacture, and a few such lamps are doubtless to be found in most laboratories. If a galvanometer or milliammeter is connected between the electrode and the negative terminal of the lamp the effect of a magnetic field upon the current is readily observed. A sufficiently strong field will suppress the current entirely, while even a weak permanent magnet produces an observable change. If the direction of the field is normal to the plane of the filament, it is found that a field sufficiently strong to noticeably weaken the current will, upon being reversed in direction, produce an *increase* in the current. This result is readily explained upon the hypothesis of negative corpuscles ; in one case these are deflected in such a way that the number striking the middle electrode is smaller with the field than without ; upon reversing the field the direction of deflection is also reversed, and the number of corpuscles that reach the electrode is increased. So far as I am aware an increase in current in such cases, due to a magnetic field, has not previously been recorded. To show the effect but requires rather a weak field. If a strong field is used the current is suppressed in all cases.

Without going into detail it is sufficient to say that the results are in complete qualitative agreement with the hypothesis of negatively electrified corpuscles.

ON CYANINE PRISMS AND A NEW METHOD OF EXHIBITING ANOMALOUS DISPERSION.

R. W. WOOD.

I have already described a method of making prisms of solid cyanine by pressing the fused dye between plates of glass, which are far superior to liquid prisms or the solid prism made by Wernicke for the purpose of exhibiting anomalous dispersion.

Until quite recently I considered that twenty or thirty minutes was about as large an angle as could be used to advantage. With such large angles very little green light gets through the prism and on viewing a source of light through the refracting edge we see merely a red and a blue image, the former being deviated more than the latter. With a new supply of the dye which we have just received I have however been able to make prisms of over one degree which transmit an abundance of green light. Viewing the incandescent loop of an electric lamp through one of these prisms, we see a most beautiful anomalous spectrum, a broad band of light with the colors arranged in the order, green, blue, violet, red, and orange. When it is remembered that the largest angle which Pflüger was able to obtain by Wernicke's method, was of but two minutes the advantage of the fusion method is apparent.

While engaged in some experiments on the dispersion of selenium, from which most beautiful prisms can be made by the same method, I was led to try the experiment of crossing one of these prisms with a small diffraction grating. Selenium has an extraordinarily high refractive index, over 3 for certain colors, and the prisms are quite transparent for the red and orange. The deviation produced by one of these prisms is about double the angle of the prism, and I was led to try the experiment of crossing one of them with a diffraction grating. On viewing an arc-lamp through the combination, the diffraction spectre were most distinctly seen on each side of the central image each one with its tail nicely curled up at the edge of the absorption band which begins in the yellow and stretches to the extreme ultra-violet. Having such excellent cyanine prisms at my disposal it occurred to me to try crossing one of these with a diffrac-

tion grating, for the purpose of showing the dispersion curve. I have usually used a spectrometer and low dispersion prism for this purpose. The grating mounted with the cyanine prism was found to be equally efficient. One has only to view an arc light through the combination. The diffraction spectra are deviated by the prism, the red ends being turned up, while the blue-green ends are turned down in a most beautiful manner. I use a photographic copy of a 2000 line to the inch grating, about 5 mms. square fastened over the refracting edge with sealing wax. The curved spectra can also be seen when the sun is viewed through the combination though less perfectly owing to its size.

In conclusion some hints regarding the construction of cyanine prisms may be of use to any wishing to repeat the experiment. The cyanine was obtained from Grüber of Leipzig, and is in the form of lumps of quite minute crystals. The old sample had a different appearance, consisting of long needle shaped crystals not caked together. A certain amount of dexterity is required to make good prisms, which can only be acquired by practice. Small rectangular pieces of thin German plate glass are prepared (measuring about 2 x 3 cms.) and a thin strip cut from a visiting card glued along the short side of one. A piece of cyanine about the size of a coarse shot is placed near the opposite side and the edge of the plate heated over a small flame until the dye fuses, holding another cover strip in the flame at the same time, in order to have both at about the same temperature. The hot edge of the cover is now to be brought down into the cyanine, and the plate gently lowered until the edge rests on the strip of card. The plates must be at once placed under pressure in a small clamp, where they are to remain until cold. I find that the flat jawed metal clamp of one of Gaertner's laboratory supports gives the best results. The pressure is to be applied close to the refracting edge of the prism only as shown in the figure. This is very important. Experience is the only guide to the degree of pressure required. With the new sample of cyanine the removal of one of the glass plates when this is desired is much easier than with the old. For most purposes however I prefer to leave the cover on, cementing the two plates together with sealing wax. It will be found that there is a very narrow strip of clear glass at the refracting edge, where the glass plates have come into

optical contact. This produces a diffraction band superposed on the anomalous spectrum, but it is so faint that it is not troublesome. It is usually necessary to turn the prism slightly to get the green part of the spectrum, that is the incidence should not be normal.

Examples Exhibited. The cyanine prism should be held with the label side towards the eye, and an incandescent lamp or gas flame turned edgewise viewed through the slit. The refracting edge (which is to the left should be turned away from the eye a little, though the eye must be brought close up to the aperture. The same thing applies when using the prism in connection with the spectrometer.

To see the dispersion curve by means of the grating and prism, one has only to view a naked arc lamp through the small rectangular aperture.

ON THE PROPAGATION OF CUSPED WAVES AND THEIR RELATION TO THE PRIMARY AND SECONDARY FOCAL LINES.

PROF. R. W. WOOD.

In a previous paper (*Phil. Mag.*, July, 1900,) I have shown the forms of the wave-fronts reflected from spherical surfaces, by means of geometrical constructions, and photographs of the actual waves.

In the present paper I shall discuss somewhat more fully the case of the reflection of a plane wave by a hemispherical mirror, where we have a reflected wave of a form which I have likened to a volcanic cone. A superficial examination of the forms might lead one to imagine that the bowl of the crater collapsed to a point at the principal focus of the mirror. This can, of course, only be true in the case of a concave spherical wave, which is only given by a parabolic mirror. We shall find, as a matter of fact, if we examine the geometrical construction, that the cusp of the wave, or the rim of the crater, which traces the caustic as I have shown, is continuously passing through a focus. In other words, the curvature of the crater increases as we go from the bottom to the rim, at which point the radius becomes zero. The inner edge is then continually passing

through a focus and appearing on the outside, building up, as it were, the sides of the cone. These wave-fronts were drawn by constructing the orthogonal surface, which was shown to be in section an epicycloid formed by rolling a circle, whose diameter was equal to the radius of curvature of the mirror, around the outside of the mirror. The evolute of this curve is the caustic, itself an epicycloid, and the reflected wave-fronts form a family of parallel curves, which are the involutes of the caustic.

Though the caustic and orthogonal surface (evolute and involute) are similar epicycloids, the reflected wave-fronts, or parallels to the orthogonal surface are not epicycloids. It may be well to point out here an error that sometimes appears in text-books on optics, namely the assumption that the wave-front, say in the case of a spherical wave refracted at a plane surface, is an hyperboloid in the second medium, because the caustic is the evolute of an hyperboloid. An hyperboloid wave will not propagate itself as an hyperboloid, nor an ellipsoidal wave as an ellipsoid (except in an anisotropic medium), the parallels to a conic being in general curves of the eighth degree. In the case above cited, we should speak of the wave-fronts after refraction as the parallels to an hyperboloid.

Let us suppose the wave to be just entering the mirror. The form of the portion which has already suffered reflection is a cusp extending around the upper edge of the hemisphere. Fig. 1.

The upper branch of the cusp is concave upward, and is the portion of the wave which left the reflecting surface first and has passed through a focus. The lower branch is concave downward, or in the direction of propagation, and represents the portion of the wave which has just left the surface and is on the way to its focus. The radius of curvature increases from zero as we go away from the cusp point along either branch, as I have said before. This cusped wave moves down the mirror, the lower branch being continually replenished by consecutive portions of the incident wave as it encounters the mirror, the upper branch being continually added to by elements of the lower branch as they pass through their foci at the cusp.

As I have said in a previous paper, the cusp traces the caustic surface, and since the wave is always coming to a focus on the cusp, the increased illumination along the caustic is accounted for.

Let us now examine the relation of these reflected wave-fronts to the primary and secondary focal lines. If we inspect the diagram usually given to illustrate the formation of focal lines (Winkelmann, p. 33, for example), it is at once apparent that the wave-front between the two focal lines is expanding along one meridian and contracting along a meridian at right angles to it, in other words, the wave is convex along one meridian and concave along the other. The form of the surface is not unlike a small bit on the inside of an anchor ring.

Consider now the diagram shown in Fig. 2, remembering that the complete wave front at this stage is formed by the rotation of this figure around the axis of the mirror. The bowl of the crater is concave along every meridian, but it is at once apparent that any portion of the outer slope has the required saddle shape, being concave in horizontal planes and convex in vertical planes. From this it is evident that the outer wall of the volcanic cone, before it crosses the axis of the mirror, always represents the portions of the wave front between the primary and secondary focal lines.

That this is true is evident when we recollect that the first focal line is formed by the intersection of rays on the caustic surface, or regarded from the wave point of view, by the passage through their foci on the cusp of the wave, of adjacent elements of the wave-front. The second focal line lies on the axis of the mirror, consequently the wave-front between the lines is that portion of the surface which has passed through a focus on the cusp, but which has not crossed the axis.

I have found that a small glass model of the wave-front shown in cross section in Fig. 2, is extremely useful in making the whole matter clear. It can be made by drawing down a large, thin tube, melting the end down flat, and then sucking it in a little.

Another useful piece of apparatus can be made by silvering the outside of a hemispherical glass evaporating dish or half of a large, round bottomed flask. The concave mirror thus formed should be mounted on a stand and a two candle power "pea" electric lamp arranged so that it can be moved along the axis of the mirror. In my second paper on the photography of sound waves, it was shown that a spherical wave starting in the principal focus of a hemispherical mirror, is reflected as a saucer-shaped wave, the curved sides of the

saucer coming to a focus in a ring surrounding the nearly flat circular bottom. If we place the lamp in the focus of the mirror, and hold a sheet of ground glass in front of it at the proper distance we can show the luminous ring and the uniformly illuminated circular area within it.

If we move the lamp to a point midway between the principal focus and the surface of the mirror we get a ring of intense brilliancy, with but very light within it.

The wave-front constructions for this condition are shown in Fig. 3., the distribution of energy being roughly shown by shading the reflected wave-fronts.

While I have brought out nothing but what would be apparent to anyone on a very cursory examination of the constructions, some of the points may be of use to those engaged in teaching elementary optics.

University of Wisconsin.

FORMULA FOR FREEZING POINT DEPRESSION.¹

WILLIAM FRANCIS MAGIE.

In the methods commonly employed for calculating the depression of the freezing point of a liquid in consequence of its containing a substance in solution, which follow the model set by van't Hoff's original method, there is not sufficient account taken of two circumstances :

1. that the cyclic process employed is not a Carnot's cycle ;
2. that certain of the quantities introduced as constants are really variable with the temperature.

In view of the accurate data recently obtained by Loomis, it becomes a matter of interest to determine whether or not the departures which his results exhibit in certain cases from the law obtained by ignoring these circumstances are due to an insufficiency in the formula or to other causes.

According to van't Hoff's law the depression of the freezing point of a solution is strictly proportional to the number of gram molecules

¹ Read by title at the meeting held on Feb. 23, 1901.

of the solute associated in the solution with a fixed mass of the solvent. In some cases Loomis's results confirm this law perfectly, in other cases nearly ; while in certain others the deviation from this law is very considerable.

If we submit a solution to the cyclic operation described by van't Hoff, taking account in so doing

1. of the latent heats of expansion of the solute, which are different at different temperatures ;
2. of the different latent heats of the solvent at different temperatures ;
3. of the specific heats of the solution in different states of concentration and of the specific heat of the solvent when solid ;
4. of the non-adiabatic character of the steps in the cyclic operations which are not isothermal ;

We may form the equations of energy and entropy applicable to this operation. In the equation of entropy Condition 4 introduces the integral $\int_t^{t_0} dt$ taken between the limits of the freezing temperature of the pure solvent and the freezing temperature of the solution.

For a very dilute solution the value of this integral, $\log \frac{t_0}{t}$, may be obtained with sufficient exactness by retaining only the first term in the expansion of the logarithm ; but for more concentrated solutions it is important to consider the second term also.

The equation obtained by the combination of the two equations of energy and entropy, which holds in any case in which an osmotic pressure exists, is much simplified in the special case of the non-electrolytes. This simplification arises from the equivalence in this case of the osmotic pressure and the latent heat of expansion, and from certain relations among the specific heats. (*Physical Review*, August, 1899.)

The final result is that the formula for the freezing point depression is that of van't Hoff with the addition of two terms in the denominator, one depending on the specific heats of the solvent in the liquid and the solid states, and the other on the osmotic pressure of the solution.

By a computation of the magnitude of these terms in the case in which one gram molecule solute is mixed with 1000 grams water,

assuming for the very dilute solution the molecular depression 1.855, we find that the effect of these terms, which are of opposite sign, only reduces this molecular depression by $1/1000$ or to 1.854, a difference far too small to be measured in the present development of the experimental methods.

We conclude that the formula obtained by the first approximation is amply sufficient for our present needs, and that departures from the law of van't Hoff must be explained on other grounds than the insufficiency of the formula.

Princeton University.

THE RELATIVE EFFICIENCY OF AN ORGAN PIPE BLOWN AT DIFFERENT WIND PRESSURES.¹

F. L. TUFTS.

(Abstract.)

At a previous meeting of the society the author described a form of organ pipe which could be used to determine the relation between the increase of energy in the predominant note of the pipe and the increase in the rate of supply of energy to the pipe by the wind blast. It was shown that for such a pipe there was a certain pressure at which the maximum per cent. of the energy supplied to the pipe was transformed into sound of the predominant note, and that the efficiency of the pipe was less for pressures either above or below this one.

The pipe used in the following experiments was similar to the one previously described. It was so arranged, however, that the distance between the air slot and the lip was adjustable, and for each change in the pressure at which the pipe was blown this distance was so adjusted as to give the maximum amount of energy in the fundamental note of the pipe. Under these conditions it was found that throughout the range of pressures used (from one to thirty centimeters of water column) the efficiency of the pipe remained prac-

¹ Presented at the meeting held on April 27, 1901.

tically constant, that is, the increase in the energy in the fundamental note was proportional to the increase in the rate of supply of energy to pipe by the wind blast. In order to obtain the maximum amount of energy in the fundamental note of the pipe at different pressures it was found necessary to increase the distance between the air slot and lip when the pressure at which the pipe was blown was increased. If the distance between the lip and air slot was not varied it was found that increasing the pressure at which the pipe was blown raised the pitch of the fundamental note slightly, the efficiency, in general, decreased rapidly, and there was only a limited range of pressures at which the pipe would speak its fundamental note. These results were found to apply to pipes having the form of mouthpiece used in ordinary steam whistles as well as to those having the common flute pipe form of mouthpiece.

The experiments showed the following difference in the action of the two forms of mouthpiece. If a pipe was blown at a given pressure it was found that with the steam whistle mouthpiece the pitch of the fundamental note could be raised slightly by moving the lip nearer the air slot while increasing the distance between the lip and air slot lowered the pitch to some extent. Just the opposite effects were in general produced by movements of the lip in the flute pipe form of mouthpiece.

The relation of these experiments to the theory of the production of tone in organ pipes was discussed in the paper.

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The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

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ERRATA.

The illustrations here given should have accompanied the article by R. W. Wood, "On the Propagation of Cusped Waves." Vol. 2, No. 1, p. 10.

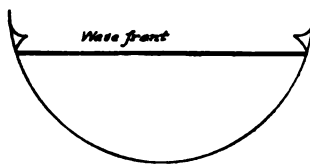


FIG. 1.

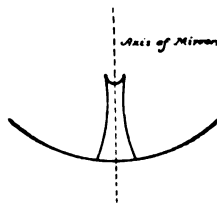


FIG. 2

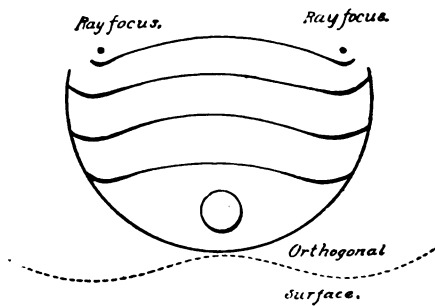


FIG. 3.

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THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Eleventh Meeting.

A joint meeting of the American Physical Society and Section B of the American Association for the Advancement of Science was held in the High School Building at Denver, Colorado, Thursday morning, August 29th, 1901.

In the absence of the President and Vice-President, Edward L. Nichols was made Chairman, *pro tempore*.

Benjamin W. Snow was elected Secretary, *pro tempore*.

The following papers were presented :—

1. Note on the supposed elongation of a dielectric in an electrostatic field. L. T. More.
2. On electro-striction. J. S. Shearer (read by E. L. Nichols).
3. The pressure of heat and light radiation. Ernest F. Nichols and G. F. Hull (read by B. W. Snow).
4. The heat of combustion of acetylene. H. A. Rands (read by title).
5. The fall of temperature through a wedge-shaped wall of glass. Arthur Ball (read by title).
6. On a new method of determining the curve of luminosity by homogeneous comparison. D. B. Brace.

B. W. SNOW, Secretary, *pro tem*.

Minutes of the Twelfth Meeting.

A regular meeting of the American Physical Society was held in Room 301, Fayerweather Hall, Columbia University, New York City, on October 26th, 1901, at 11 o'clock, President Michelson presiding.

On motion, It was resolved that in view of the services in commemoration of the late Professor Rowland, now being held in Baltimore, the following telegram be sent to President Ira Remsen, of Johns Hopkins University, on behalf of the Society.

"The American Physical Society now in session, joins you in the appreciation of the loss to Science of its distinguished ex-President Rowland."

The following papers were presented during the morning session :

1. Effects of stationary sound waves upon unignited gas streams. F. L. Tufts.
2. Photographic study of air movements in a speaking organ pipe. F. L. Tufts.
3. Note on the use of the Arons' mercury lamp in certain color experiments. Ernest Merritt.

In the afternoon the Society met with the American Mathematical Society during the reading of the following paper :

4. On the theory of elastic plates. Jacques Hadamard.

The Society then re-assembled in Room 301. During the afternoon session the following papers were presented :

5. Note on recent measurements of subterranean temperatures. Wm. Hallock.
6. An entropy meter. A. G. Webster.
7. The audibility of sound over water and over grass. A. G. Webster.
8. The anomalous dispersion of sodium vapor. R. W. Wood.
(Read in abstract by the Secretary.)

COUNTER ELECTROMOTIVE FORCE OF THE ARC.¹

H. J. HOTCHKISS.

(Abstract.)

In an article published in 1897 by Professor A. Blondel, "On the Phenomena of the Electric Arc",² an experimental test, used to indicate whether there is a large counter electromotive force in the arc or not, consisted essentially in interrupting the current for one two-hundredth part of a second and connecting the arc in series with a galvanometer during the second six-hundredth part of a second. The experiment could, therefore, give no direct evidence relating to what occurs during the first six-hundredth of a second after the impressed electromotive force is removed. To obtain such evidence was primarily the object of the experiments described below.³

For obtaining a record of what occurs immediately after the impressed electromotive force is removed, photographic recording galvanometers⁴ were used. The needle, or moving part, first used had

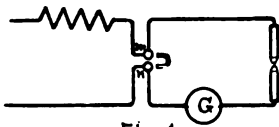


Fig. 1.

a natural vibration frequency of about 5100 complete cycles per second, and weighed one milligram. The speed of the photographic plate past the slit along which the spot of reflected light

vibrated was about 360 centimeters per second.

Figure 1 shows a diagram of the apparatus and connections used first. The impressed electromotive force was removed by connecting the mercury cups *mn* by a short thick copper staple. The galvanometer had low resistance and negligible self induction. When the deflected needle was released by the abrupt removal of the impressed E.M.F., the record should be a trace of the natural vibra-

¹ Presented at the meeting held on April 27, 1901.

² *London Electrician*, Vol. 39, page 615. *Comptes rendus*, Vol. 125, p. 164, etc.

³ The preliminary experiments were made by Mr. N. H. Brown and the writer while Mr. Brown was taking graduate work in Physics in the University.

⁴ For description, etc., see *Physical Review*, March, 1899, and *Electrical World*, July 22, 1899.

tion of the needle if there were no source of E.M.F. in the galvanometer circuit. A rapidly decreasing counter E.M.F. would be indicated by the first return throw of the needle reaching farther from the axis than the point of release, or at least farther than it would go by its own inertia.

To obtain a trace due to inertia alone for comparison with the arc trace, connections were made as shown in Fig. 2. By turning the double throw switch *S*, the arc was replaced by twelve incandescent lamps in parallel. Pairs of curves were thus obtained for arc and

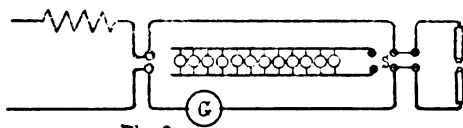


Fig. 2.

incandescent lamps. The first throws ranged between 15 and 54 millimeters, according to the sensitiveness of the different needles used. Solid carbons were used with about 10 amperes and 45 to 50 volts.

If at the instant of removal of impressed E.M.F. there were a back E.M.F. of two volts, which died away in one ten-thousandth of a second at such a varying rate that its average value for that time would be one-third of its maximum value, the amplitudes of the first few vibrations would each be increased about one-fourth millimeter, which could be readily detected by comparing pairs of curves.

A careful inspection of the curves led to the conclusion that there was no perceptible increase of the first forward and return throws, and consequently no rapidly decreasing back E.M.F. as large as that of the supposed case above. Instead of the first return throw being increased, some curves showed a slight decrease; and the most noticeable characteristic difference between the pairs of curves was the approximate equality of the first and second forward throws with the arc in circuit, and the regular decrement of amplitude of the second forward throw with the lamps. These differences were interpreted as indicating a small, rapidly increasing back E.M.F. This agrees with the back E.M.F. curves obtained in connection with another part of the work.

The second part of the experimental work was an attempt to determine the variation of resistance of the arc vapors after the main

current is interrupted, the principal object being to find how large it becomes in one-thousandth of a second ; then, assuming the rate of rise to be uniform for that time, the value at any intermediate instant can be approximated for use in computing the back E.M.F. required to produce a measurable difference between a pair of curves.

Two methods for finding resistance were used, the connections for which are shown in Figs. 3 and 4.

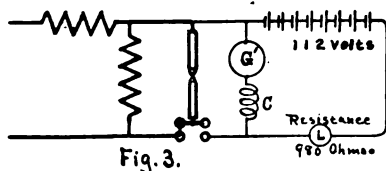


Fig. 3.

For the first, a practically constant current was maintained in an auxiliary circuit containing the galvanometer. The main circuit was broken, and about one-thousandth of a second later the arc was placed in parallel

with the galvanometer. It was found that when the auxiliary current was reversed that the current curves were different, indicating a small back E.M.F.

From these curves values of resistance and back E.M.F. were computed as shown by curves I and I' , in Figs. 5 and 6.

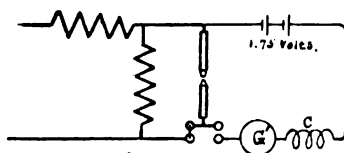


Fig. 4.

The second method made use of a constant E.M.F. of 1.75 volts, and the arc was placed in series with the galvanometer instead of multiple. The average values of

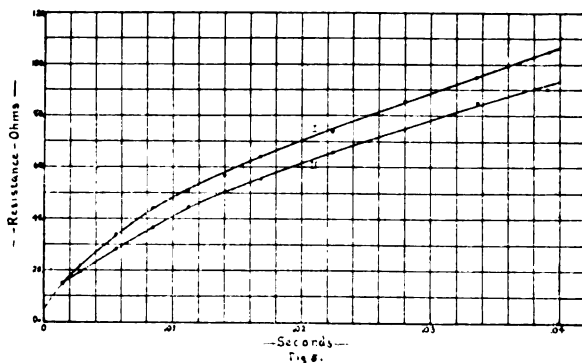
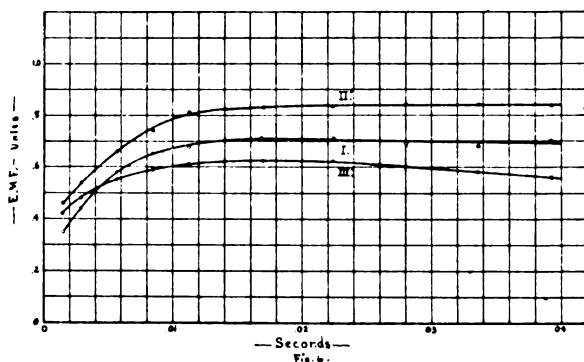


Fig. 5.

resistance and back E.M.F. obtained by this method are given by curves II and III' in Figs. 5 and 6. The low values at the beginning of the E.M.F. curves are not due to the self induction of coil O ,

since it would affect the first values in opposite directions, making one too large and the other too small.

As a check, a curve was taken with connections as shown in Fig. 4 except that the two cells were left out, leaving the arc as the only



source of E.M.F. The current thus obtained, together with the average resistance from curves I and II, plus the resistance of galvanometer and coil, gave the values of E.M.F. shown by curve III' in Fig. 6.

The experiments lead to the following conclusions :

1. If there is a back E.M.F. dying out in one ten-thousandth of a second it does not have an average value for that time as large as two-thirds of a volt.

2. At the instant that the impressed E.M.F. is removed the back E.M.F. is probably very near zero and increasing instead of decreasing.

3. After the first ten-thousandth of a second, there is a back E.M.F. which rises rapidly at first, then more slowly, to a maximum of less than one volt in about one-fiftieth of a second.

Cornell University, April, 1901.

SPECIFIC HEATS OF ELECTROLYTES IN SOLUTION.¹

WILLIAM FRANCIS MAGIE.

It was shown by Schüller, and afterwards more fully by Thomsen, that the specific heats of many aqueous solutions are not in accord with the Joule-Woestyn law. When Thomsen's results are examined it is found that the solutions he used are all electrolytes, in which dissociation takes place; and it is natural to suppose that the departures shown by these solutions from the simple law of mixtures may be due to the dissociation, especially as it has been shown that in many non-electrolytes, where there is no dissociation, the law of mixtures holds good.

The simplest supposition that can be made in pursuance of this idea is that the solvent retains its specific heat unchanged, and that that the solute when dissolved breaks into two portions, the undissociated and the dissociated portions, each of which possesses a constant specific heat. I find however, that a formula constructed on this basis would require, to represent the facts, the inadmissible assumption of a negative specific heat for the dissociated portion of the solute. To avoid this, I assume that a portion of the solvent, proportional to the degree of dissociation, reacts with the dissociate solute, so that its freedom, and therefore its specific heat, is diminished. The heat capacity of a solution may then be expressed by the formula :

$$\phi = Ms + m\sigma - nk,$$

in which M and m are the masses, s and σ the specific heats, of the solvent and solute respectively, n is the degree of dissociation, and k is a constant.

This formula was tested by an examination of the heat capacities given by Thomsen for several solutions, of which the dissociation was also known. It was found that, with but one exception, the heat capacities of the solutions considered could be obtained from the above formula with constant values of σ and k . The solutions which conformed to this law were those of sodium chloride, potassium chloride, ammonium chloride, hydrochloric acid, sulphuric acid, potassium hydrate, and sodium hydrate. The exception was offered by potassium nitrate.

¹ Presented at the meeting held on April 27, 1901.

As examples of the accuracy with which this formula reproduces the heat capacities, I cite the following :

Na Cl.			H Cl.		
$K = 0.7, m\sigma = 39.$			$K = 0.4, m\sigma = 3.6.$		
N	<i>Obs.</i>	<i>calc.</i>	N	<i>Obs.</i>	<i>calc.</i>
200	3578	3584	200	3561	3568
100	[1788]	[1788]	100	[1770]	[1770]
50	892	892	50	873	873
30	536	536	---	---	---
20	361	361	20	339	339

N denotes the number of gram-molecules of water in the solution, containing one gram-molecule of the solute. The numbers in brackets were those used in determining $m\sigma$. When we plot Thomsen's specific heats for sodium chloride, it becomes clear from the shape of the curve that the value given for $N = 200$ is too low, and using the value obtained by smoothing the curve we get for the heat capacity 3585, in accord with the calculated value. For a similar reason, we may properly consider the true value of the heat capacity for $N = 200$ in the case of hydrochloric acid as being 3568, also in accord with the calculated value.

I have chosen the substances above given for illustration, because they were also used by Mathias (C. R. 107, p. 524, 1888) to illustrate an empirical formula which he employed to represent Thomsen's values of the specific heats of solutions. It will be seen on an examination of Mathias' results that his formula does not accord so well with the observations as the one given above.

A further study of this subject will require an extended study of the specific heats of electrolytes pushed to a higher degree of accuracy than that attained by Thomsen, and including the examination of more dilute solutions. I hope to be able to take up that work in the near future.

Princeton University.

THE ELASTIC PROPERTIES OF HELICAL SPRINGS.¹

J. W. MILLER, JR. INTRODUCED BY R. S. WOODWARD.

(Abstract.)

This paper presents the results of an investigation carried on during the past two years by the author at Columbia University. It shows :

First, the precise law of variation of the pull for a finite elongation of a helical spring.

Secondly, that in elongating a close-wound spring it undergoes twist up to a maximum amount and then untwists with increasing elongations.

Thirdly, that observation of the elongation of maximum twist gives the ratio of the modulus of twist to the modulus of bending of the wire ; and that observation of the greater elongation of zero twist gives an independent value of said ratio.

Fourthly, that the properties thus revealed give precise methods for measuring the modulus of twist, the modulus of bending, Young's modulus, the modulus of rigidity, and Poisson's ratio for any helical spring.

The values of these constants for several springs of different sizes and different metals were exhibited.

A PRELIMINARY COMMUNICATION ON THE PRESSURE OF LIGHT AND HEAT RADIATION.²

E. F. NICHOLS AND G. F. HULL.

The experiment consisted of two parts: (1) The determination of the light pressure by observing the deflection, either static or ballistic, of a torsion balance when one vane of the balance was exposed to light, and (2) the determination, in ergs per second, of the intensity of the light falling upon the vanes.

¹ Presented at the meeting held on April 27, 1901.

² Presented at the meeting held on August 29, 1901.

The image of an aperture, upon which the rays from an arc lamp were concentrated by two condensing lenses, was focussed in the plane of the glass vanes placed symmetrically with regard to a rotation axis held by a quartz fibre of known torsion coefficient.

The torsion balance was covered by a bell jar connected to pressure gauges and a mercury pump. To eliminate the disturbing action due to the residual gas in the receiver, the following devices were used: (1) The vanes were silvered and highly polished, thus making the absorption small and the reflection percentage large. (2) The silver surface of one vane was turned toward, and that of the other from, the light, thus making the effect of the gas action and light pressure in the same direction on one vane and in opposite directions on the other. (3) The pressure of the air in the bell jar was varied and the pressures were chosen in the vicinity of that pressure at which the gas action was very small. (4) The length of exposure of light on the vane in most of the observations was short. The gas action which begins at zero and increases with the length of exposure was thus reduced in comparison with the instantaneous action of the radiation pressure.

By means of an inclined glass plate placed in front of the aperture a portion of the incident light was thrown on a thermopile. The deflection of a galvanometer connected with the latter gave the *relative* light intensities.

Two methods of determining radiation pressure were used: (1) The vane was exposed continuously to the light until the turning points of the vibration of the balance showed that static conditions had been reached. The other vane was then exposed. Finally the whole suspended system was turned through 180° and the vanes were exposed in turn. The mean of the angles of deflection, multiplied by the torsion coefficient of the fibre and divided by the lever arm, gave the force in dynes acting on the vane. (2) The vanes were exposed for a quarter of the period of the suspended system. The period, damping coefficient, torsion coefficient, and lever arm being known, the value of the radiation pressure could be found.

The two methods gave practically the same result except for the air pressures for which the gas action was large.

The energy falling upon the vanes was measured by means of a

bolometer consisting of a thin disc of platinum, about the size of the vanes, covered with platinum black. The bolometer, occupying exactly the position which the glass vane had previously occupied, was made one of the arms of a Wheatstone bridge. The bridge was balanced, the bolometer exposed to the light, and the throw of the bridge galvanometer read. Later the disc was heated by an electric current which entered and left at two equipotential points on the bridge current and the galvanometer throw was again read. The current strength and the resistance of the disc being known, the activity of the disc is given by $i^2 R \times 10^7$ ergs per second. The readings of the thermopile before mentioned made it possible to reduce all observations to a constant light intensity.

If E = energy per second falling upon a surface, a = the percentage of the radiation reflected, v = the velocity of light, then, theoretically, the value of the radiation pressure is $\frac{(i + a) E}{v}$.

The experimental value of the pressure as found by the authors was about 80% of the theoretical value.

ELECTROSTRICION.¹

J. S. SHEARER.

One of the unsettled questions regarding the action of the electric field upon matter relates to changes of length and volume. Numerous observers have reported variations in these quantities when the dielectric of a condenser was subjected to electrostatic strain. Others have found no such effect, or have believed that the effects described could be readily explained as due to other causes. As the supposed elongation is very small, it is essential that the method used in the measurement should be as refined as possible, and the conditions should be such as to produce as large a variation in length or volume as could be secured without rupture of the material.

In the present work, a refractometer was used to indicate changes of length as it was believed to be superior to other optical or semi-mechanical methods. The movable mirror of a Michelson refractometer was detached from its mounting, and fixed to the end of the dielectric to be tested. Adjustment was secured by means of a slow

¹ Presented at the meeting held on August 29, 1901.

motion screw at the other end of the test piece. The entire apparatus was mounted on a marble slab, placed on a pier in the basement, where the temperature was practically constant. The source of electromotive force was a Thomson dynamo-static machine, which was capable of continuous operation regardless of weather conditions. The potential to which the dielectric was subjected could be controlled by the use of a spark gap in shunt with the metallic plates of the condenser, or by simply increasing the leakage on the line. In order to secure a gradual rise in potential, large capacity could be placed in the circuit.

Experiments were first made with glass, and also with hard rubber rods placed between a metallic plate and a glass having tin foil on the outer side so that the test piece was a portion of the dielectric of the condenser. Later, long thin tubes of glass silvered internally and externally were used and in some cases, glass tubes filled with mercury and with tin foil for the outer electrode were tried.

The fringes were viewed by a telescope with a micrometer eye piece, so that any movement could be accurately measured.

The glass tubes used were from 75 to 80 centimeters in length, and from .8 of a millimeter to 2 millimeters in thickness. The external radii varied from 3 millimeters to 17 millimeters. Assuming that a movement of $\frac{1}{20}$ of a band width could be observed with certainty, a change of .0147 microns in length could be measured.

The potential differences were steadily increased in each case until the tube was punctured, care being taken to eliminate glow discharge as far as possible. No movement exceeding $\frac{3}{8}$ of a band width was ever observed, and in many cases the fringes remained absolutely quiet. When vibratory motion synchronous with charge and discharge was observed, it seldom exceeded $\frac{1}{4}$ of a band width, and in all cases disappeared after a comparatively small number of trials. After this, attempts even on the following day and with the terminals interchanged failed to produce any effect. These elongations are much below what would be expected from the results reported in most cases, and might be explained without reference to electrostatic strain.

The conclusion indicated by these experiments up to the present time would be that if electrostriction actually exists, its magnitude is much less than has been generally supposed.

PHOTOGRAPHIC STUDY OF THE VIBRATIONS IN THE MOUTH OF A SPEAKING ORGAN PIPE.¹

F. L. TUFTS.

(Abstract.)

The Schlierin method was employed in studying the vibrations of the tongue of air in the mouth of a speaking organ pipe. A stopped pipe was used, the two sides of which were of plate glass. The air with which the pipe was blown, passed over a surface of ether before entering the pipe, thus changing its optical density, and making it readily visible in the Schlierin apparatus. A number of instantaneous photographs were taken showing the different positions of the tongue of air in the mouth of the pipe. The direction of the vibrations within the pipe was obtained by introducing a small jet of unignited illuminating gas into the pipe near its mouth and photographing it on the same plate with the tongue of air.

Reproductions of some of the photographs will be given in the January number of the *Physical Review*, 1902.

A STUDY OF THE ACTION OF SOUND WAVES ON UNIGNITED JETS OF GAS.²

F. L. TUFTS.

(Abstract.)

In this work the Schlierin method of investigation was employed and photographs were taken giving a number of instantaneous positions of a jet of unignited illuminating gas when acted on by sound waves. The orifice from which the gas issued was rectangular in shape and was 4.0 mm. by 0.5 mm. in cross section. It was placed about 6 cm. from the open end of an organ pipe, speaking a fundamental note of about 100 vibrations a second. A thin rubber diaphragm was stretched across the inside of the pipe at the position of the node of the fundamental note, thus protecting the jet from the

¹ Presented at the meeting held on October 26, 1901.

² Presented at the meeting held on October 26, 1901.

action of direct currents of air. The jet tube was placed so as to expose the broad side of the jet to the action of the to and fro motion of the air particles in the sound wave.

The photographs exhibited showed the sinuous shape of the gas jet near the orifice, the fan shaped spreading of the particles as they receded from the orifice and, for low velocities of efflux, the division of the jet into two.

A simple geometrical construction was described which gave positions for the gas stream agreeing well with the positions shown in the photographs.

The paper will be published in full in the January number of the *Physical Review*, 1902.

NOTE ON THE USE OF THE ARONS' MERCURY LAMP AS A SOURCE OF ILLUMINATION IN CERTAIN COLOR EXPERIMENTS.¹

ERNEST MERRITT.

The light from an arc between mercury terminals, as in the case of the Arons' lamp, is chiefly due to three intensely bright lines in its spectrum, these lying respectively in the violet, the green, and the yellow. The yellow line is somewhat less intense than the other two. Since these three lines correspond approximately with the three primary color sensations of the Young-Helmholtz theory, the light from the Arons' lamp does not appear widely different from white. In judging its color by looking at the lamp itself, rather than at objects illuminated by it, one would probably speak of the light as being greenish or bluish. In reality, however, the red end of the spectrum is entirely lacking; and this lack is strikingly shown as soon as the light is used to illuminate colored objects in which the red is prominent. Seen by the light of the Arons' lamp, a piece of bright red cloth, for example, appears to be black.

It will readily be seen that the peculiar character of the light from the mercury arc can be utilized to advantage in a variety of illustrative experiments on color. For many purposes the light may be regarded as white light from which the red rays have been completely

¹ Presented at the meeting held on October 26, 1901.

removed. When colored worsteds, such as are used in the ordinary Holghren test for color blindness, are illuminated by this light the reds appear as blacks, or as shades of gray. In mixed colors, the eye sees only what is left after the red constituent is removed; the purples, for example, appear to be violet or blue. After looking at colored objects as seen by the light of the mercury lamp one is able to appreciate the probable sensations of dichroic vision. If the Holghren test is applied to the normal eye, this source of illumination being used, the results are almost identically the same as those obtained with a red-blind eye in daylight.

One of the most striking of the color changes shown by the Aron's lamp is in the case of autumn leaves. Leaves which have changed their color entirely, so as to be of a deep red color in daylight, appear to be black, as one would anticipate. But leaves in which the change is not yet complete, so that they are yellow rather than red, appear by the light of the mercury lamp as a deep green. In fact, their appearance is not greatly different from that of leaves in which the autumn coloring has not yet begun. It appears that in such leaves only a part of the chlorophyl has undergone a change, so that the reflected light contains green, from the unmodified chlorophyl, as well as red. The resultant color sensation is yellow. But if the leaf is illuminated by light that contains no red, as is the case with light from the mercury arc, it can only appear as green. For lecture illustration this experiment may be made more effective by arranging so that the change from daylight to the Arous' lamp, or *vice versa*, may be made suddenly.

NOTE ON THE REPORT OF THE BRITISH ASSOCIATION
ON UNDERGROUND TEMPERATURES, PROF. J. D.
EVERETT, CHAIRMAN.¹

W. HALLOCK.

This is the twenty-second report of this Committee and is devoted especially to the gradient under Keweenaw Point, Lake Superior, and to the deepest of all holes at Paruschowitz, near Rybnik, in Silesia.

¹ Presented at the meeting held on October 26, 1901.

After a full discussion of the abnormal gradient reported a few years ago from the Calumet and Hecla mines, and the observations of A. C. Lane and others, the conclusion is inevitable that no especial abnormality exists and that the gradient reported by Lane, 1° for 107 ft. for the Calumet district, is not far from the truth. Very many corroborative observations give rates varying from 100 ft. to 115 ft. for 1° F.

As to the Rybnik well a description of its sinking is given in "Glückauf" for 1895, p. 1273-7, by Kobrich.

The details of the temperature observations have never been published, and were furnished to Prof. Everett for his report.

This well was commenced in January, 1892, and finally stopped in August, 1893. It attained the depth of 2003.34 meters (6653 ft.). Was put down with a rotating drill. It tapered in diameter from 92 mm. at the top, to 69 mm. at the bottom. Temperature observations were made with sets of six thermometers lowered upon a rod. Mud prevented convection currents.

The observations from 6 to 533 meters show a straight gradient of 1° C. for 39.6 meters; from 533 to 1680, a wavy gradient averaging 1° C. for 32.9 meters; and the lower part 1680 to 1959, 1° C. for 31.0 meters. Or, comparing 12.1° C. at a depth of 6 meters with 69.3° at 1959 meters we get an average gradient of 1° C. for 34.1 meters, of 1° F. for 62.2 ft.

There is some doubt as to the correctness of the value 12.1° at 6 meters. An extended discussion of mean annual temperatures leads to the conclusion that a better value would be 8.3° C. This will give 1° C. for 32 meters, or 1° F. for 58.3 ft. A similar treatment of the Schladabach observations gives 1° C. for 35.6 meters, or 1° F. for 65 ft. It will be remembered in this connection that the gradients at Wheeling, W. Va., and at West Elizabeth, near Pittsburg, Pa. were 1° F. for 74.3 ft. and 71.5 ft. respectively.

Emphasis is laid upon the fact that in earth temperature work it is in general much more difficult to obtain satisfactory values for the surface temperature than for the deep localities, and that these surface values can generally be best obtained from the mean annual temperature of the place.

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PUBLISHED QUARTERLY

BOARD OF EDITORS

J. S. AMES

M. I. PUPIN

ERNEST MERRITT

VII.

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THE AMERICAN PHYSICAL SOCIETY
1901

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J. S. AMES, M. I. PUPIN, ERNEST MERRITT.

The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

Andrus & Church, Printers, Ithaca, N. Y.

THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Thirteenth Meeting.

The Annual Meeting of the American Physical Society was held in Fayerweather Hall, Columbia University, New York City on Friday, Dec. 27, 1901, at 11 o'clock.

In the absence of the President, Vice-President Webster presided.

The following papers were presented during the morning session :

1. A suspected case of the production of color by the selective electrical resonance for light waves of very minute metallic spheres. R. W. Wood.

2. Report on Electro-striction. Louis T. More.

3. Further Experiments on Electro-striction. J. S. Shearer.

4. The Transmission of Excited Radioactivity. E. Rutherford.

5. Excited Radioactivity and Ionization of Atmospheric Air. E. Rutherford and S. J. Allen.

The afternoon session was called to order at 2:15 P. M.

The President announced the result of the mail ballot for officers and members of the council, Messrs. Day and Trowbridge having been appointed by the President as tellers. The following were declared elected :

OFFICERS.

President—Albert A. Michelson.

Vice President—Arthur G. Webster.

Secretary—Ernest Merritt.

Treasurer—William Hallock.

MEMBERS OF THE COUNCIL.

To fill the vacancy caused by the election of A. G. Webster as Vice-President, on April 27, 1901. A. L. Kimball.

For the full term of four years. D. B. Brace and Carl Barus.

The following papers were presented during the afternoon session :

6. Note on Drude's Elektronentheorie. E. H. Hall.

7. The Disturbances of a Plumb-bob suspended on a steel wire.
Wm. Hallock.

8. A Thermograph for Earth Temperatures. Wm. Hallock.

9. The Viscosity of Water determined by the aid of Capillary
Ripples. F. R. Watson.

10. Magnetization of Steel at Liquid Air Temperatures. C. C.
Trowbridge.

11. The Pfaundler Calorimeter. W. F. Magie.

12. Standards of High Electrical Resistance. H. C. Parker.

13. Variation of Contact Resistances with change of E.M.F. H.
C. Parker.

14. On a Ruling Engine for Diffraction Gratings. A. A. Michel-
son (read in abstract by the Secretary).

An informal report was presented by the Treasurer, showing a
balance on hand of about \$1,000.00. [An abstract of this report is
given below.]

On motion of Mr. Hallock the Vice-President and Secretary were
appointed a committee to draw up a memorial to Congress on behalf
of the Society favoring the passage of a law for the adoption of the
Metric System.

Adjourned.

TREASURER'S REPORT.

FROM THE ORGANIZATION OF THE SOCIETY TO DEC. 31, 1901.

1899.

Receipts:

Annual dues	\$ 235 00
Life membership fee	50 00
Total	\$ 285 00

Disbursements:

Supplies and postage, Treasurer	\$ 11 39
Supplies and postage, Secretary	24 84
Total	\$ 36 23
Balance forward	248 77
Total	\$ 285 00

TREASURER'S REPORT.

35

1900.

Receipts:

Balance forward	\$ 248 77
Annual dues	562 50
Interest on previous balance	8 75
Total	\$ 820 02

Disbursements:

Expenses of Secretary	50 03
Expenses of Treasurer	10 20
Printing Bulletin	136 55
Total	\$ 196 78
Balance forward	623 24
Total	\$ 820 02

1901.

Receipts:

Balance forward	\$ 623 24
Life membership fee	50 00
Annual dues	\$ 585 00
Interest on balance	21 83
Total	\$1,280 07

Disbursements:

Expenses of Secretary	\$ 148 98
Expenses of Treasurer	16 38
Printing the Bulletin	112 81
Total	\$ 278 17
Balance forward	1,001 90
Total	\$1,280 07

STATEMENT OF PRESENT CONDITION OF SOCIETY'S FINANCES,
DECEMBER 31, 1901.

Cash in the hands of the Treasurer	\$1,001 90
Arrears of annual dues for 1899	\$ 5 00
Arrears of annual dues for 1900	42 50
Arrears of annual dues for 1901	22 50 70 00
Total assets	\$1,071 90
Total liabilities, none.	

WILLIAM HALLOCK,
Treasurer.

REPORT ON ELECTROSTRICTION.¹

BY LOUIS T. MORE.

(Abstract.)

In a recent number of the *Philosophical Magazine* I published some notes on electrostriction, in which I attempted to answer the criticisms of Dr. Sacerdote, as it seemed to me that he had misinterpreted several statements made in an earlier paper.

Since then important contributions to the subject have been made. Professor Ercolini, in the *Nuovo Cimento*, describes a series of experiments on glass cylindrical condensers, charged by armatures detached from the dielectric, the intermediate spaces being filled with a non-conducting fluid. The advantage of this arrangement I pointed out in my first paper. He states that he observed lateral bending of the tube which he was able to allow for and also a rapid quivering motion of the interference bands at the moment of the spark discharge, both of which are in accordance with my observations. Besides these he also states that he could observe a slight increase in length due to the electrical stress in the ether, evidently too small to measure. He then applies the charge directly to the glass, and finds an increase in length, unaccompanied by lateral bending and disturbing motions. The thickness of the glass was 1.6 mm. and its length, 60 cm.; for a spark length of 5 mm., the elongation was 0.64 of a band. Cantone's results, assuming the influence of the thickness to be as its inverse square, call for a much smaller deflection.

Besides the above, Mr. J. S. Shearer has obtained results in the Cornell Laboratory which are in entire accordance with my own, as he finds no deflection when using glass. He employs the method of interference of light which the Italian writers claim to be more exact and sensitive than my own.

It is not altogether certain that we should expect an appreciable elongation at right angles to the lines of force, if we adopt the equation of Dr. Sacerdote. By his theory $\frac{\delta l}{l} = (a + k_1) \frac{K V^2}{8 \pi d^2}$,

¹ Presented at the meeting held on Dec. 27, 1901.

where a is the inverse of Young's modulus and k_1 is the specific change in the dielectric constant with pressure. The other letters have their usual significance. Now it is evident that if k_1 is negative, the expansion might well be nearly or quite eliminated. Our knowledge of the relation between the dielectric constant and pressure rests, so far as I can find, on the experiments of three writers, which disagree as to whether k_1 is positive or negative. They also have been criticised and apparently justly.

Further results with apparatus even more delicate are evidently necessary before the question can be definitely settled, and I trust in the near future to present such to the Physical Society.

*University of Cincinnati,
January, 1902.*

TRANSMISSION OF EXCITED RADIOACTIVITY.

E. RUTHERFORD.

(Abstract.)

One of the most interesting properties of the radioactive substances, thorium and radium, is their power of communicating temporary radioactivity to all bodies¹ in their neighborhood. If a wire, charged strongly negative, is placed in a closed metal vessel containing thoria or radium, the excited radioactivity is confined entirely to the negative electrode. If the wire is charged positively, it remains inactive, but the excited radioactivity is produced on the walls of the vessel. In previous papers the author has examined the excited radioactivity produced by thorium compounds and has shown that it is intimately connected with the power of giving off a radioactive emanation. Curie² has examined the excited radioactivity produced by very active samples of radium when no electric field is acting. Dorn³ found that samples of radium prepared by P. de Haen Hannover, gave off an emanation similar to thoria. The emanation from thoria loses half its radiating power in about one

¹ E. Rutherford, *Phil. Mag.*, Jan. and Feb. 1900.

² C. R. 1900 and 1901.

³ Natur gessellschaft. Halle. 1900.

minute, but the emanation from radium continues radiating strongly for several weeks. On the contrary, the excited radioactivity due to thoria falls to half its value in eleven hours, while that from radium decays much more rapidly. The rate of decay of the excited radiation from radium is not regular and depends largely on the purity of the radioactive material employed.

The emanations from thorium and radium behave in all respects like radioactive gases or vapours. They diffuse rapidly through gases, through porous substances like cardboard, and unlike the gaseous ions which they produce in their path, pass through plugs of cotton wool and bubble through solutions with no absorption.

The author holds the view, that these emanations are in some way the direct cause of excited radioactivity. In support of this, the following facts may be stated :

(1) Only the substances which emit emanations, viz., thorium and radium, compounds have the power of exciting radioactivity.

(2) If the emanating power of thoria or radium is partly destroyed by strongly heating, the power of exciting radioactivity diminishes in like ratio.

(3) Excited radioactivity can be produced in substances if the emanation and not the radioactive substance is present. On the other hand, the power of exciting radioactivity by the radioactive substance itself, is very greatly diminished by a current of gas passed over it, which carries away the emanation. In the case of radium, the emanation can be confined in a closed vessel for several days and still produce excited radioactivity. The radiating power of thoria emanation decreases too rapidly to permit of such an experiment.

The characteristic property of excited radioactivity is that it can be confined to the kathode in a strong electric field. It is probable, therefore, that the radioactivity is due to the transport, in the electric field, of positively charged carriers of some kind.

The experiments now to be described completely support this view and show that the carriers travel in an electric field with about the same velocity as the positive ion.

PRINCIPLE OF THE METHOD.

The method employed to determine the velocity of the carrier is a modification of one already used in a determination of the velocity

of the negative ion, produced at the surface of a metal by ultra-violet light. It depended on the use of an alternating electric field. A direct *P. D.* was commuted by means of a revolving commutator into an alternating *P. D.* of known frequency. If such an alternating field is applied to two parallel plates, between which a radioactive emanation is kept uniformly distributed, equal amounts of excited radioactivity are produced in each electrode.

If, in series with an alternating *P. D.* = E_0 a battery is placed of E.M.F., E_1 less than E_0 , the positive carrier moves in a stronger electric field in one-half alternation than in the other. A carrier consequently moves over unequal distances during the two half alternations, since the velocity of the carrier is proportional to the strength of the electric field in which it moves. It follows from this that the excited radioactivity will be unequally distributed over the two electrodes. If the frequency of alternation is sufficiently great, only the positive carriers within a certain small distance of one plate can be conveyed to it, and the rest, in the course of several succeeding alternations, are carried to the other plate.

Let d = distance between the parallel plates.

T = time of a half alternation.

ρ = ratio of the excited radioactivity on the plate which has less to the sum of radioactivity on both plates.

Then, assuming the carriers are produced at a uniform rate at each point between the plates and that no carriers disappear by recombination, it can be shown that

$$K = \frac{2 (E_0 + E_1)}{E_0 (E_0 - E_1)} \cdot \frac{d^2}{T} \cdot \rho$$

In the experiments the values of E_0 , E_1 , d^2 and T were varied and the general results were in agreement with the equation.

APPARATUS EMPLOYED.

For experiments on thoria emanation, a thick layer of thoria was placed in a shallow copper vessel inside an ebonite box, 11 cms. square and 3 cms. deep, which was tightly waxed down to a metal base. The thoria was completely covered with two layers of filter paper, which cut off most of the direct radiation, but readily allowed the emanation to pass through. The apparatus was rendered air

tight by a metal lid, dipping into a mercury trough round the top of the ebonite box. At the beginning of an experiment a square sheet of aluminium foil was placed over the paper covering the thoria, a zinc plate on top of the ebonite box, and the lid placed in position. This was done as quickly as possible and the alternating electric field was then applied.

The emanation rapidly diffused through the paper and thin aluminium foil and distributed itself between the plates in the electric field. After an interval, varying in the experiments from 20 to 90 minutes, the aluminium and zinc plate were removed and their radioactivity tested in the usual way by a delicate quadrant and electrometer. The ratio of the excited radioactivity on the two exposed plates was thus determined. This ratio was found to be independent of the time the plates were left before testing, as the radioactivity on each plate decays at the same rate.

The amounts of thoria used in the experiments varied from 25 to 100 grammes. The amount of excited radioactivity in a given time varied with the amount of thoria, but the ratio of the excited activity on the two plates was not altered.

In the course of the experiments, it was found that a plate, which has been exposed a short time in the presence of thoria emanation, after being removed, gradually *increased* in radioactive power for several hours. The amount of increase varied with the time of exposure to the emanation, but in short exposures it increased to three or four times its initial value. For exposures of several hours, the effect is not so marked and is difficult to detect after a day's exposure.

The same apparatus and method was employed in some of the experiments with radium. The radium in my possession was very feebly emanating at atmospheric temperatures. Use, however, was made of the fact,¹ previously observed by the author, that the amount of emanation from radium increases several thousand times by heating the radium below a red heat.

The emanation from heated radium was first carried by a current of air into a small metal cylinder. The openings were then closed and the emanation thus collected could be used for experiments extending over several days. At the beginning of an experiment

¹ *Physikalische Zeitschrift*. 1901.

the metal plates were placed inside an ebonite box and the alternating field applied. By means of side tubes in the ebonite box, a small proportion of the emanation from the cylinder was introduced between plates by a slow current of air through the cylinder. The side tubes were then closed. After an exposure of about half an hour, a current of air was passed through the ebonite box to clear away the emanation from the vessel. The plates were then removed and their radioactivity tested. On account of the initial rapid decay of the excited radioactivity from radium, it was difficult to make satisfactory comparisons of the radioactivity of the plates until after an interval of 15 minutes, when the rate of decay became slow enough to admit of accurate determination of the ratio. All the experiments showed that the ratio was independent of the interval that elapsed before comparison.

Most of the experiments so far have been made on the emanation from thoria. Comparisons of the velocity of the carrier have been made over a wide range of period, of alternation, and of voltage. The general results obtained were in complete agreement with the theory put forward. With constant voltage the value of ρ was found to diminish with increase of speed of alternation. With a constant speed of alternation, the value of ρ increased with the voltage.

It was found that, unless sufficiently high voltages were used, the values of the velocity obtained were too high. This is due in great measure to recombination of ions between plates. When an E.M.F. is applied, not sufficient to remove all the ions to the electrodes before recombination occurs, the excited radioactivity is distributed on both positive and negative electrodes. In the theory we have assumed the potential gradient uniform between the plates. In practice, this is far from being the case, especially when the ionization is strong between the plates. The experiments of Child and Zeleny have shown that there is a sudden drop of potential close to each electrode, so that the electric field is much greater near the plates than at the centre.

For this reason, when the speed of alternation is so great that only a small fraction of the total excited radioactivity is produced on one electrode, the values calculated from the simple theory are too large.

The following table is an example of some of the results obtained

for different voltages and distances between the plates. Temperature 18° C. Air fairly dry.

PLATES 1.30 CMS. APART.

$E_0 + E_1$	$E_0 - E_1$	Alternations per sec.	ρ	K
75	50	57	.17	1.7
152	101	57	.27	1.25
225	150	57	.38	1.17
300	200	57	.44	1.24

The value of K is given in cms per sec. for a potential gradient of 1 volt per cm.

For the last example, since the carrier travelled over a distance greater than 1.30 cms. during each half alternation, a modified form of the equation was necessary to calculate the velocity.

The value 1.6 cms. per second for 50 volts is too high for the reasons explained above.

PLATES 2 CMS. APART.

$E_0 + E_1$	$E_0 - E_1$	Alternations per sec.	ρ	K
273	207	44	.37	1.47
300	200	53	.286	1.45

Experiments on the velocity of the carrier of excited radioactivity due to radium are not yet completed. Sufficient has been done however, to show that the effects of variation of time, of alternation and of voltage, are very similar to those obtained in the case of thorium. The value of the velocity of the carrier is certainly not very different from that observed in the case of thorium. The results, in the case of radium, are complicated by a distribution of excited radioactivity, which is produced even on the positive electrode in a strong electric field when the emanation is quickly blown out between the plates. Experiments are in progress to find out, if possible, the cause of this effect and to eliminate it from the experiments.

It appears as if the value of the velocity of the positive carrier of excited radioactivity is the same or, at any rate, not very different, from the velocity of the positive ion produced in gases by Röntgen or Becquerel Rays. In a recent determination, Zeleny¹ found the velocity of the positive ion to be 1.36 cms. per second for a potential gradient of one volt per cm. at atmospheric pressure and temperature.

¹ Phil. Trans. Roy. Soc. 1900.

In considering the question of the method in which the positive carrier becomes the vehicle of transmission of excited radiation, two explanations present themselves. The first is one put forward in a previous paper, viz., that the positive ion produced by the emanation has the power of condensing the radioactive material of the emanation on its surface, in a similar way that water vapour condenses on the negative ion in a moist gas. Each carrier would thus carry a minute quantity of radioactive matter to the negative electrode. The other explanation, suggested to me by Prof. J. J. Thomson, is that the molecules of the emanation have the power emitting negatively charged corpuscles in a manner similar to radium in a solid state. Each molecule which had emitted a negative corpuscle would have a positive charge and would thus be carried to the negative electrode. The results, however, observed for thoria at low pressures are apparently against this view. The excited radioactivity for pressures of the order of one mm. of mercury is not completely concentrated on the kathode, but is spread over the positive electrode as well. Before definitely deciding between the two explanations, further experiments are necessary on the distribution of excited radioactivity on the electrodes at very low pressures.

In the experiments we have been considering, the distribution and transference of excited radioactivity in an electric field. The same explanation also applies when no electric field is acting. In that case the excited radioactivity is produced on the electrodes by the diffusion of the positive carriers to their surface.

*Macdonald Physics Building,
December 14, 1901.*

THE DISTURBANCES OF A PLUMB-BOB SUSPENDED ON A STEEL WIRE.¹

WILLIAM HALLOCK.

(Abstract.)

In the course of work in the No. 5 shaft of the Tamarack Mining Co., it became necessary to establish two points at a depth of over 4,000 ft. in order to run off a transverse to meet one from another shaft. For this purpose two plumb lines were used, consisting of fifty-pound iron weights upon No. 24 steel piano wire. They were about seventeen feet apart and hung entirely free from walls, girders, etc.

When their distance apart was measured it was found that they were about an inch farther apart at the bottom than at the top. This was entirely unexpected and various suggestions were offered to account for it, only to be abandoned. Air currents would undoubtedly cause a certain amount of disturbance, but they would tend to draw the bobs together. The attraction of the nearer wall will not come into consideration, inasmuch as both bobs are in an enclosed space, surrounded by homogeneous walls.

The very high magnetisation of the casings in oil and gas wells led me to the suggestion that the divergence might be due to a repulsion of two north magnetic poles formed at the lower ends of the wires by the vertical component of the earth's magnetic field. The "inclination" being something over 75° the vertical component would have a value of 0.8 or 0.9, which would be able to induce quite considerable magnetic intensities.

A rough calculation showed that the repulsion to be expected was of the same order of magnitude as the force observed.

When the wires were 16.33 ft. apart at the top, the deviation was 0.09 ft.

When the wires were 17.58 ft. apart at the top, the deviation was 0.07 ft.

The ratio of the squares of the distances is about 77 to 90.

From this it will be seen that the force is a repulsion that is inversely proportional to some power of the distance, probably the square.

¹ Presented at the meeting held on Dec. 27, 1901.

In order to test the matter farther two plumb lines were set up in the shaft of the laboratory here, and direct observations were made. In the first series two lines were used, one of copper and one of piano wire. They were so mounted upon the same bar that they could be rotated around a vertical line midway between them and parallel to them. In this way the iron was at one time due north of the copper and at the other time due south of it.

Under these conditions if the steel wire became magnetised by the earth's field with a magnetic north pole at the bottom, then this pole would be pulled toward the north by the earth's field. This pull would have the effect of bringing the iron nearer to the copper when it was south of the copper and farther away in the opposite position. The actual observations showed the two wires to be 0.3 mm. nearer when the iron was south than when the iron was north.

In the next case two pieces of soft iron wire 50 ft. long were hung from the bar by pieces of copper wire about 25 ft. long, so that the upper third of the line was fine copper, to give freedom in support ; and the lower two-thirds were of iron to become magnetised and repel each other. The two lines were about 5 mm. apart.

Here again the lines were about 0.3 mm. farther apart at the bottom than at the top. This repulsion is considerably greater than would be produced by any magnetisation of the wire that could reasonably be attributed to a field of unity or less. This fact led to the question as to whether there might be free magnetism at points along the wire other than at the ends. The following table will show the result of an inspection of the wires along their length with a small compass :

<i>Distance on Wire.</i>	<i>South Wire.</i>	<i>North Wire.</i>	<i>Resulting Effect.</i>
Top end	south, strong	south, strong	repulsion, strong
5 ft. down	" weak	" weak	" weak
10 "	" "	" "	" "
15 "	north, weak	" "	attraction, weak
20 "	" "	north "	repulsion, "
25 "	" "	neutral	none
30 "	south, weak	" "	" "
35 "	north, "	" "	" "
40 "	" "	north, weak	repulsion, weak
45 "	south, weak	south, "	" "
50 "	north, strong	north, strong	" strong

From the above it will be seen that a preponderance of repulsion prevails all along the line, sufficient to account for the observed deflections.

It may well be that masses of iron outside the wires may also have contributed either to the deflecting forces or to the magnetic induction.

The above considerations would seem to justify the conclusion that the deflections observed in the "Tamarack No. 5" were due to magnetic causes and that the use of steel wire in long plumb lines is to be avoided whenever a considerable degree of accuracy is desired.

Fayerweather Physical Laboratory,

Columbia University.

A RECORDING THERMOMETER FOR SUBTERRANEAN TEMPERATURES.¹

WILLIAM HALLOCK.

(Abstract.)

At the Brooklyn Meeting of the American Association in 1894, Prof. W. H. Bristol of Stevens Institute, exhibited and described a form of recording thermometer in which a metallic reservoir was connected with an ordinary recording pressure gage by means of a long copper capillary tube of about $\frac{1}{32}$ inch inside diameter.

The instrument now shown differs from that of Prof. Bristol essentially in the recording mechanism. The oil is allowed to expand into a series of two or three thin corrugated chambers, similar to those used in aneroid barometers. The dilation of these capsules is considerable and capable of doing work in overcoming friction, etc., since on the one hand we have the expansive force of the oil, and on the other the full atmospheric pressure, this ensures positive motion to the recording pen.

In the new instrument constructed the bulb is a hollow copper sphere of 15 cm. diameter, connected by a tube 3 meters long, 1.6 mm. outside and 0.8 mm. inside diameter.

The expansion capsules are two, about 7 cm. diameter, and 0.5 cm. thick; the lever connections multiply 1 to 5, and 1° is about 2 mm., the oil used is common kerosene.

The whole is mounted on the base of a Richard's thermograph, and the Richard's recording drum is used.

Fayerweather Physical Laboratory,

Columbia University.

¹ Presented at the meeting held on Dec. 27, 1901.

ON A RULING ENGINE FOR DIFFRACTION GRATINGS.¹

A. A. MICHELSON.

(Abstract.)

The principal points of interest in the engine are the following:—

1st. It is proposed to rule gratings having a ruled space of 12 to 15 inches with lines 4 to 6 inches in length.

2nd. For lines of this length the accuracy of the ways upon which the grating holder moves must be so great that the average angle between any two parts shall be less than $\lambda/4l$ (where λ = length of a light wave, and l the length of the ruling).

This degree of accuracy is practically unattainable by the method of the mirror and telescope—and the interference method described in a paper entitled “Measurement by light-waves” (*Am. Journ. Sci.*, Feb., 1890) was employed.

3rd. The motion of the grating carriage is continuous instead of by steps; in consequence, the lines are not straight but are approximately sine curves. This can readily be shown to have no appreciable effect upon the resulting spectrum.

4th. In order that so large a ruled surface shall have a resolving power proportionate to its extent, the rulings must have a much higher relative accuracy. It is better to say that the absolute accuracy must be the same as for a small grating.

This means that the average displacement of any line from its correct position must be less than $\frac{1}{4}\lambda$ or $\frac{1}{8}\mu$. Accordingly the screw must have no greater average error than this.

It would be very difficult to attain this high order of accuracy by the usual microscopic method; but by means of the interferometer, measurements to this order of accuracy are quite easy.

It would be difficult—though not impossible as I hope to show—to construct a screw which would itself be accurate to this degree, but for the present purpose it is quite as effective, and far more simple, to observe, by the interferometer the actual errors, and then apply an automatic correction.

5th. In a previous paper “The Echelon Spectroscope” the desirability of concentrating the greater part of the light into a single

¹ Presented at the meeting held on Dec. 27, 1901.

spectrum, was pointed out, and methods were suggested by means of which such a result might be secured.

One of the simplest would be to select such a ruling diamond as to produce furrows of the requisite form. This has to a certain extent been accomplished by the customary but very unsatisfactory method of trying various diamonds and turning these in all manner of ways *until* the required result is produced.

It is proposed to cut the diamond to various forms and so produce furrows of any desired form.

Some preliminary work indicates that diamonds so cut are at least as durable and in every way satisfactory as those which have been used without artificial preparation.

6th. Experiments are in progress which it is hoped will considerably reduce the first cost of the unruled surface. Among these may be mentioned the silvering of a glass surface, and the covering of such silver surface with platinum or other metal which does not tarnish.

In conclusion it may be stated that it is hoped to produce gratings which will resolve lines whose actual separation is a thousand times less than that of the sodium lines D_1 and D_2 ; and to concentrate from 50 to 75 per cent of the incident light into a single spectrum.

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The Bulletin of the American Physical Society is published quarterly. It contains the minutes of all meetings of the Society and abstracts of the papers presented, as well as various announcements, and other matter, of interest to members of the Society. Communications regarding the Bulletin should be sent to Ernest Merritt, Ithaca, N. Y.

Papers intended for presentation at any meeting of the Society should be placed in the hands of some member of the Program Committee as promptly as possible, and should be accompanied by an abstract suitable for publication in the Bulletin. If the authors desire it such abstracts as are received at least ten days prior to the meeting will be printed and distributed with the program.

Andrus & Church, Printers, Ithaca, N. Y.

THE AMERICAN PHYSICAL SOCIETY.

Minutes of the Fourteenth Meeting.

A Regular Meeting of the American Physical Society was held in Room 301, Fayerweather Hall, Columbia University, New York City on Saturday, February 22, 1902.

President Michelson presided.

The following papers were presented :

1. Velocity of Light. A. A. Michelson.
2. On Magnetostriction in Bismuth. A. P. Wills.
3. The Transmission of Sound through Solid Walls. F. L. Tufts.
4. Experimental Mechanics—the Spherical Pendulum. A. G. Webster.
5. The Flower-like Distortion of Coronas, due to graded cloudy condensation. C. Barus.
6. On persistent Nuclei produced by shaking solutions of solids, liquids, or gases (like HCl).
7. On the Current between a Cold Metal and an Incandescent Carbon Kathode at Low Pressures. E. Merritt and O. M. Stewart.

It was moved and carried that the Council be requested to arrange a summer meeting of the Society in connection with the meeting of Section B of the American Association for the Advancement of Science at Pittsburg.

Adjourned.

THE VELOCITY OF LIGHT.¹

A. A. MICHELSON.

(Abstract.)

The fact that the velocity of light is so far beyond the conception of the human intellect, coupled with the extraordinary accuracy with which it may be measured, makes this determination one of the most fascinating problems that fall to the lot of the investigator.

The experiment of measuring the velocity of light was originally devised by Arago, as a means of furnishing a crucial test between the two great rival theories of light. History has recorded the triumph of the undulatory theory, as the result of the classic experiments of Foucault and Fizeau.

It was found in the course of these and subsequent experiments that the experimental determination of the absolute value (V) of the velocity of light was capable of so high a degree of accuracy that instead of obtaining V by observations of the eclipses of Jupiter's satellites, or the aberration of the fixed stars, together with the astronomically calculated value of the sun's distance (with results of relatively small accuracy)—the process is exactly reversed; so that the experimental value of V , together with observed values of the light equation, or the constant of aberration, furnishes a far more accurate value of the sun's distance than can be obtained by rare and costly expeditions for observing the transit of Venus. This appears quite clearly if we contrast the numbers given by Professor Harkness,² which give the solar parallax as obtained from astronomical data³

$$8.78 \pm .05,$$

with the results given by Professor Todd of the same quantity, as determined by the combination of velocity of light with the light equation or with the constant of aberration.

¹ Presented at the meeting held on Feb. 22, 1902.

² The numbers here given are not Professor Harkness' estimates, but only a rather rough guess from the data he presents, which I think are nevertheless of about the right order of magnitude.

³ Am. Jour. Sci., 1881.

In an article on "Solar Parallax from the Velocity of Light,"¹ Professor D. P. Todd gives the following resumé of the determinations of the solar parallax from L , the light equation, and from α , the constant of aberration.

"The elements of sensible uncertainty considered are :

"1. Uncertainty in the determination of terrestrial velocity of light. . . . I am disposed to think that the limit of uncertainty of the velocity of light concluded above (299,920 kilometers) may be fairly taken at seventy kilometers.

"2. Uncertainty in the coefficient of the light equation from observations of the satellites of Jupiter. . . . The amount of uncertainty is probably not far from one second of time.²

"3. Uncertainty in the the constant of siderial aberration. I conceive that a variation of 0.025 in this well-determined constant³ will not be regarded far from the limit of uncertainty. . . .

"4. Uncertainty in the relation of the absolute terrestrial velocity to the velocity in space. . . . The impossibility of an experimental determination of this relation renders the assumption of identity necessary.

"In conclusion, then, all the experimental determinations of the velocity of light hitherto made give, when combined with astronomical constants, the mean equatorial horizontal parallax of the sun,

$$8.''808 \pm 0.006$$

The corresponding mean radius of the terrestrial orbit is

$$149,345,000 \text{ kilometers.}''$$

Roughly speaking, it appears that the velocity-of-light method of obtaining the solar parallax is about ten times as accurate as the astronomical method.

It also appears that in the last-named method the order of accuracy in the determination of the astronomical factors is about one-thousandth part.

¹ Am. Jour. Sci., Vol. XIX, p. 59.

² This is taken from the observations of Delambre, 493.2, weight 1, and of Glasenapp, 500.84 \pm 1.02, weight 2.

³ Professor Todd accepts Struve's value 2''.0445.

The undulatory theory does not specify the nature of the undulations, and it is no argument against it that the special mode of motion assumed by Fresnel (vibrations of an elastic solid, which so elegantly explains all the known phenomena of light) has met with some serious objections. If, according to Maxwell, these undulations are electromagnetic changes, these objections no longer apply, and this electromagnetic theory of light is now universally accepted.¹

In accordance with Maxwell's theory, the ratio of any electric or magnetic unit measured electrostatically to the same unit measured electromagnetically, the ratio usually designated as Maxwell's v , must be equal to the velocity of light. The verification of this relation would be a powerful argument (were any such needed) in favor of the theory; and in fact the value of v agrees as well with V as do the separate accepted values of v among themselves.

M. Abraham in a report to the International Congress of Physics gives the following resumé of these determinations:

Himstedt.....	3.0057	×	10 ¹⁰
Rosa.....	3.0000	×	10 ¹⁰
J. J. Thomson.....	2.9960	×	10 ¹⁰
H. Abraham.....	2.9913	×	10 ¹⁰
Pellat.....	3.0092	×	10 ¹⁰
Hurmuzescu.....	3.0010	×	10 ¹⁰
Perot and Fabry.....	2.9973	×	10 ¹⁰

M. Abraham accept the mean value

$$v = 3.0001 \times 10^{10}$$

which he regards as probably correct to the thousandth part, and concludes with the following significant remark:

“ Etant donné l'intérêt qui s'attache à la détermination de la vitesse v , il paraît désirable que de nouvelles expériences soient entreprises. La précision des anciennes mesures peut être dépassée; toutes les méthodes s'y prêtent. Il y a encore à réduire quelques corrections trop incertaines; il y a à simplifier quelques mesures auxiliaires trop complexes, et par ce nouvel effort on pourra sans

¹ While the electromagnetic theory gives a satisfactory explanation of light and goes a long way toward the explanation of the mechanism of radiation, yet it seems not at all unlikely that a return to something analogous to the now discarded elastic solid theory may be necessary to explain electromagnetic phenomena.

aucune doute, apporter dans la mesure de v une précision, supérieure a celle aujourd'hui acquise pour la vitesse de la lumière."

Again, Blondlot and Gutton, in the same report, give the following resumé of some of the best determinations of the velocity of Hertzian waves :

Blondlot.....	302,200 km/sec
Blondlot.....	{ 296,400 " "
	{ 298,000 " "
Trowbridge and Duane	300,300 " "
MacLean	299,110 " "
Saunders	{ 298,200 " "
	{ 299,700 " "

Messrs. Blondlot and Gutton do not make any estimate of the most probable value, but doubtless the mean of the preceding results,

$$299,130 \pm 1000$$

cannot be far from the truth. The authors conclude as follows :

" Ils (ces valeurs) sont sensiblement égaux au rapport des unités électromagnétique et électrostatique de quantité d'électricité, comme la théorie de Maxwell l'indique, et aussi à la vitesse de la lumière. Il y a un intérêt capital a rechercher si cette égalité des trois nombres est seulement approximative, ou si elle offre un caractère absolu ; on devra donc s'efforcer, dans les déterminations ultérieures de la vitesse de propagation des ondes électromagnétiques, non seulement d'atteindre la plus grande exactitude possible, mais aussi de déterminer le degré d'approximation des nombres obtenus."

It would appear then that there is but little doubt that in the near future both these determinations will be made with at least the same high order of accuracy as obtains in the measurement of the velocity of light. In this case any possible difference in the resulting values would not cast any doubt upon the electromagnetic theory, but would doubtless be traceable to the enormous difference in the conditions determined by light-waves on the one hand and electric oscillations or static charges on the other. On the contrary, such a difference might almost certainly be predicted, and would probably throw much light on the structure and mode of action of dielectrics.

Having reviewed in some detail the order of accuracy attained in

the astronomical elements which are to be combined with V , and the electro-magnetic results which are to be compared with V , let us consider the actual order of accuracy obtained in the measurement of V itself.

Concerning this, as in the cases just reviewed, a considerable diversity of opinion will prevail concerning the relative weight which should be attributed to the various determinations.

The following table is taken from Prof. Newcomb's report :

(1) Foucault, 1862.....	298,000
(2) Cornu (1), 1874.....	298,500
(3) Cornu (2), 1878.....	300,400
(4) Cornu (2) as discussed by Listing.....	299,990
(5) Young and Forbes, 1880-81.....	301,382
(6) Michelson (1).....	299,910
(7) Michelson (2).....	299,853
(8) Newcomb (selected results).....	299,860
(9) Newcomb (all observations).....	299,810

There is no doubt that the weights which should be assigned to these results vary enormously. Still, in view of the limited number, and keeping in mind the criticism of M. Cornu, which will be presently referred to, it may be of interest to find the mean of these nine values, giving them equal weight. The result is

$$V = 299,664$$

with an average difference from the mean of 600 kilometers.

But the results (1), (2), are admitted to be only first approximations, and (5) is undoubtedly affected by some serious constant error ; so that a much closer approximation to the true value will be obtained by combining (3) or (4), the mean of (6) and (7), and (9).

The first combination gives :

Cornu.....	300,400 \pm 300
Michelson	299,882 \pm 60
Newcomb	299,810 \pm 60

Giving these equal weight we find

$$V = 300,030$$

with an average difference from the mean of about 250.

If, however, we take Listings's value of Cornu's results, we get

Cornu	299,990
Michelson	299,882
Newcomb	299,810

Giving for the mean

$$V = 299,890$$

with an average difference from the mean of about 60.

In a paper presented to the International Congress in 1900, M. Cornu expresses serious doubt concerning the order of accuracy of the results obtained by means of the revolving mirror, and, giving equal weights to the two methods regardless of the number of determinations, and ignoring Listing's discussion of his own results, gives as his estimate of the most probable value of the velocity of light

$$V = 300,130$$

with average difference from the mean of 270.

The criticism of M. Cornu embraces the following points :

1. Can the ordinary laws of reflection be applied to the case of a mirror in rapid rotation.
2. Can the ordinary laws of reflection be applied to the case of a light-ray whose axis moves with a velocity comparable with the velocity of light.
3. Does the dragging along entrainment of the light waves in the air vortex close to the mirror affect the displacement.

These criticisms have been carefully considered by H. A. Lorentz¹ who states that " Quoiqu'elles (quelques considerations. . . .) laissent encore beaucoup à désirer au point de vue de la rigueur, elles me semblent bien propres à dissiper les doutes que je viens de rappeler."

It seems to me that M. Lorentz has satisfactorily answered M. Cornu's questions; and my own estimate of the most probable value of V agrees with the second result given above, namely

$$V = 299,890 \pm 60$$

Nevertheless an experimental determination which should more or less completely avoid the necessity for the consideration of these

¹ Sur la méthode du miroir tournant pour la détermination de la vitesse de la lumière." Arch. Néer des Sciences, Ser. II, T. VI, p. 303.

questions, or at least materially diminish any error which could possibly arise, even if they were valid; and which, in any case, would furnish one more independent result to be combined with the very few reliable ones already obtained, would surely be welcome.

The preceding exposition makes it clear that the measurements and observations to be combined with or to be compared with the velocity of light, namely :

1. Astronomical observations of L and α
2. Electromagnetic ratio v
3. Velocity of Hertzian oscillations

are all capable of measurement with an order of accuracy which even now approaches, if it does not equal, that of the measurement of the velocity of light.

This, it seems to me, is a sufficient excuse—if any were needed—for once more attacking the problem.

The following plan suggested itself during the experiments upon the “relative motion of the earth and the luminiferous ether.”¹

The essential feature is the combination of a grating with a revolving mirror, which combination acts as a toothed wheel; the grating space representing the distance between the teeth, the radius being the distance from the revolving mirror to grating.

It was proposed to utilize this combination in an attempt to solve the problem of the “relative motion” by measuring the velocity of light *in one direction*, that is, without returning the light to the source. This was before the celebrated work of Hertz showed that the electrical impulses (which were to be used to establish the required phase relation between the two revolving mirrors) would be affected in the same way as would the light-waves themselves.

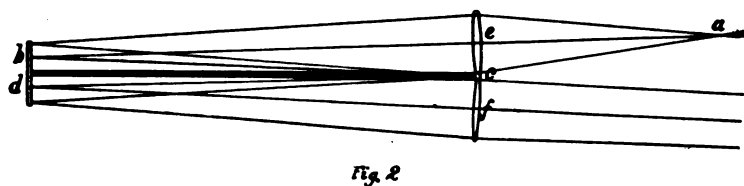
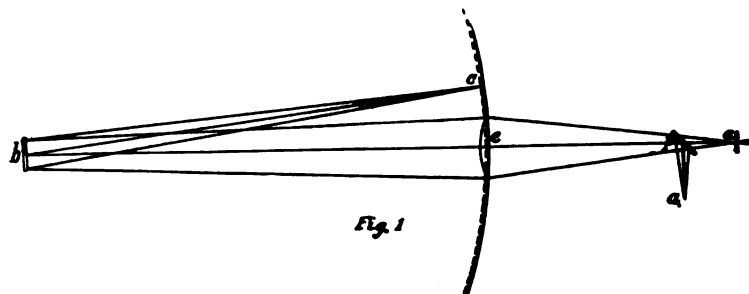
(It may also be noted in this connection that the method proposed in the same article, and illustrated by Fig. 1, is also not sound.)

It may also be worth mentioning that some preliminary experiments, made about two years ago, have shown that it is not entirely impossible to employ a mechanical method of keeping the two revolving mirrors in a constant phase relation. For instance, it was shown that the vibrations of a tuning-fork could be transmitted over

¹ Am. Jour. of Science, Vol. XXXIV, Nov., 1887.

a mile of piano-wire with a diminution of amplitude of less than one half.

The plan proposed is virtually a combination of the methods of Foucault and Fizeau. The essential feature of the observation of eclipses corresponding to the latter method, while the production of the eclipses is brought about by a revolving beam of light as in the former method.



Figures 1 and 2, in which the lettering is the same, will illustrate the essential features, subject to such minor modifications as experiment may suggest.

The light starts from a slit at *a*, passes through a lightly silvered glass plate *P* and a lens *e* and falls upon the upper half of the revolving mirror *b*. Thence it proceeds to the grating *c*, upon the surface of which it forms an image of the slit. It is thence reflected to the lower half *d* of the revolving mirror, which reflects the beam through the lens *f* to the distant mirror upon the surface of which the second image of the slit is formed. The light then retraces its course and returns to its source at *a*, part being reflected to *a*, for convenience of observation by the eyepiece.

The limit of closeness of the grating space is determined by the aperture of the revolving mirror viewed from *c*.

If the "radius" *bc* is 3 meters and the revolving mirror is 6 cm.

wide, this angle will be 0.02 ; and the breadth of the diffraction image at c will be of the order $\lambda/0.02$, or, say, $1/40$ mm. The grating space should therefore be at least $1/20$ mm. and probably better, 0.1 mm. If the number of revolutions is 250 and the distance to the fixed mirror be 3 kilometers, the displacement of the first image over the grating surface will be 18 cm., corresponding to 1800 eclipses. There need be no difficulty in counting the order of the eclipse observed, if the speed is gradually increased to its final value. The fractions could probably be observed correctly to something like 2%, so that this element of the computation for V could be measured to something like one part in a hundred thousand.

This same or even a higher order of accuracy may be obtained in the measurement of all other elements. Previous experiments have shown that the speed of the mirror may be obtained by means of a rated tuning fork to within one in 100,000.

The measurement of the distance may be made directly on a base line especially prepared for such work to within one in 200,000.

Finally the grating may be calibrated to an order of accuracy depending on the angle subtended by the diffraction fringes, *i. e.*, $1/40 \times 1/3000$, or less than one in 100,000.

It seems not unreasonable to hope that with proper care and patience the value of this great fundamental constant of Nature may be found to within five kilometers or less.

It will be noted that in the form of experiment here proposed, the more serious of the difficulties pointed out by M. Cornu no longer exist, or are very much diminished, while the possible accuracy is greatly increased. It may be hoped, therefore, that the result of this combination of the methods of Foucault and Fizeau will be to reconcile the differences which thus far seems to exist between the results of the work of their respective followers.

EXCITED RADIOACTIVITY AND IONIZATION OF ATMOSPHERIC AIR.¹

E. RUTHERFORD AND S. J. ALLEN.

(Abstract.)

The experiments of Elster and Geitel² and C. T. R. Wilson³ have conclusively shown that a well insulated charged conductor placed inside a closed vessel gradually loses its charge and that this loss of charge is due to a small spontaneous ionization of the volume of air inside the closed vessel. Wilson calculated from his results that about 20 ions per c.c. are produced in the gas per second. Quite recently Elster and Geitel⁴ have shown that a negatively charged conductor, placed in the open air, becomes temporarily radioactive. This radioactivity decays in the course of a few hours and is very similar to the excited radioactivity produced in substances by the action of thorium and radium compounds. This radioactivity, in the same way as one the authors have shown for the excited radioactivity due to thoria, can be partly removed by solution in acids. On evaporating the solution, the activity is transferred from the solution to the sides of the vessel.

In the experiments of Elster and Geitel and Wilson, the amount of ionization of atmospheric air has been determined by observing the rate the leaves of a charged electroscope of special construction fall together. This method of determination is, in general, slow and in many cases does not allow of sufficient variation of experimental conditions.

In the present experiments the authors have utilized a sensitive quadrant electrometer for examination of the ionization and excited radioactivity produced by air.

The electrometer employed is a modification of the Dolezalek electrometer which is described in *Verh. d. D. Physik, Ges.* 3, 1901. It is of the ordinary quadrant type with a very light needle

¹ Presented at the meeting held on Dec. 27, 1901.

² *Physikalische Zeitschrift*, Nov. 24, 1900.

³ *Proc. Roy. Soc.*, March, 1901.

⁴ *Phys. Zeit.*, 1901.

of silver paper and suspended by a fine quartz fibre. The apparatus, as constructed by Herr Bartels, of Göttingen, was for determination of small P.Ds. for electrochemical work. For our purpose it was necessary to completely alter the insulation and method of connection of the quadrants. In the present experiments, the needle was charged at intervals of two days by lightly touching needle by a fine wire connected to a battery of 200 volts. It was found that the needle did not lose more than 10 per cent. of its charge in 24 hours. The damping of the needle, on account of its lightness, was fairly rapid and no extra damping vane was required. The deflection was observed by a telescope and scale at a distance of 2 metres. The zero point was found to be very steady and readings, if necessary, could be made to $\frac{1}{10}$ mm. For the first suspension employed, the electrometer gave a deflection of about 1800 mms. of scale, corresponding to one volt P.D. between the quadrants, when the needle was charged to 200 volts. This suspension was accidentally broken in the course of the experiments and was replaced by a quartz fibre which gave only about $\frac{1}{4}$ of this deflection for the same voltage. When dealing with the very small rate of discharge, which is produced by the spontaneous ionization of air, it is very essential that every precaution should be taken to guard against external electrostatic disturbances. The electrometer and all the connecting wires were enclosed in gauze cylinders connected with earth. The floor and woodwork in the immediate neighborhood of the testing apparatus were covered with metal connected with earth. The separation of the quadrants was done by means of a special mercury key operated from a distance by a cord.

The insulating substances necessary in experimental arrangements were completely diselectrified by means of flames.

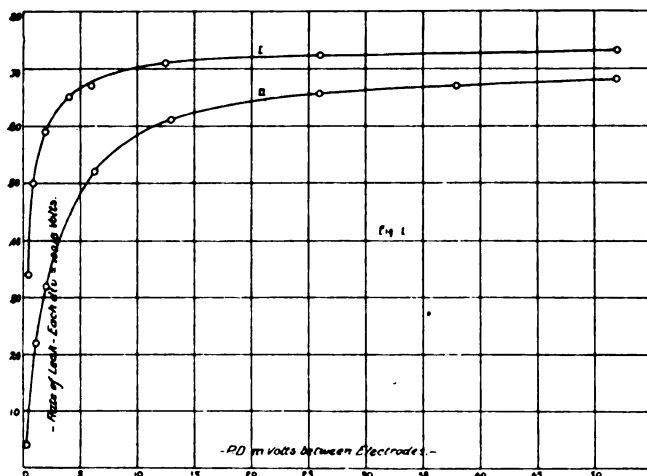
Ionization of atmospheric air.

Preliminary experiments showed the current observed by means of an electrometer between cylinders depended only on the volume of the gas between the two cylinders and not on the nature of the electrodes.

The following experimental arrangement was used to determine the number of ions produced per c.c. per second in the air and the

variation of the ionization current with the P.D. between the electrodes.

The ionization current was observed between two concentric zinc cylinders 154 cm. in length, 25.5 and 7.5 cms. in diameter. The cylinders were placed vertical and the bottom of the cylinders closed. The large cylinder was closed at the top by a zinc plate, in the centre of which was a circular opening slightly larger than the internal cylinder. A flange, fixed round the top of the inner cylinder, rested on an ebonite ring. Between ebonite and the zinc plate was placed a ring of thin metal, connected to earth, which rested on a similar ring of a partial insulator like cardboard. The



thin metal ring connected to earth served as a guard-ring, so that however large the P.D. between the cylinders, no current could leak across the insulator to the inner cylinder. The inner cylinder was connected to electrometer in the usual way. The outer cylinder was connected to one pole of a battery, the other pole of which was earthed.

The electrometer needle showed quite a rapid movement due to the ionization current between the electrodes with a P.D. of a few volts between the cylinders.

The cylinder was made fairly air-tight and allowed to stand undisturbed. Observations of the ionization current between cylinders

were made at intervals for over a month. In order to avoid corrections for the variation of the sensitiveness of the electrometer, the ionization current between two parallel insulated plates, due to a standard sample of uranium oxide was observed at the same time.

The curves, Fig. I, show the relation between current through the gas and the voltage applied. Curve I was taken after the gas had been undisturbed for a month inside cylinders. Curve II several hours after ordinary air of the room had been introduced into the apparatus. The current for about fifty volts is nearly the same in both cases; the general shape of the ionization curves is very similar to those observed for ionization of air by Röntgen and Becquerel rays. On account of the very small amount of ionization in the gas and consequent slow rate of recombination of ions, the maximum current is reached for a very small voltage. The difference in curves I and II is probably due to the presence of dust particles in the gas in the latter case. Some of the ions in their slow passage between electrodes give up their charges to the dust nuclei and thus apparently increases the rate of recombination of the ions throughout the volume of air. It will be observed that in Curve I the maximum current is nearly reached for a P.D. of 5 volts. The capacity of the electrometer, cylinder and insulators was 150 *ES* units, when 1 mm. division of electrometer corresponded to .00182 volts. The average value of the movement of the electrometer, for observations extending over more than a month, was 100 divisions in 132 seconds for 50 volts between cylinders.

The ionization current between cylinders was thus

$$\begin{aligned} &6.9 \cdot 10^{-4} \text{ } ES \text{ units} \\ &\text{or } 2.3 \cdot 10^{-13} \text{ ampères.} \end{aligned}$$

The volume of air between cylinders was 71200 cc. Taking the value¹ of $6.5 \cdot 10^{-10}$ *ES* units as the charge on an ion, the number of ions produced per c.c. per second is 15.

This is not very different from the value 20 found by Wilson using an electroscope method.

No certain difference was observed in the ionization current in the cylinder for a period of time extending over one month.

The production of excited radioactivity in the air suggested the

¹ J. J. Thomson, *Phil. Mag.*, 1898.

view that possibly a radioactive emanation was present in the air. If this is so, its radiating power decays very much more slowly than the emanation due to radium.

Production of excited radioactivity.

A special series of experiments were undertaken to determine the rate of diminution with time of the excited radioactivity produced on a negatively charged surface.

In one experiment an insulated brass rod, 8 feet long, exposed outside a window, was kept at a potential of about $-100,000$ volts by means of a large frictional machine. After an hour's exposure the rod was removed and placed inside a testing cylinder, and the ionization produced by the excited radioactivity between the cylinders determined with the electrometer at regular intervals. When the rod was positively charged, no excited radioactivity was produced.

In other experiments, a long copper or lead wire was suspended in the large attic of the laboratory, where there was no chance of contamination of the air by radioactive substances in air in the laboratory. The wire was kept at a potential of $-20,000$ to $-30,000$ volts for several hours by a Wimshurst machine driven by a motor. The wire was then quickly wound on an iron frame and placed inside a testing cylinder.

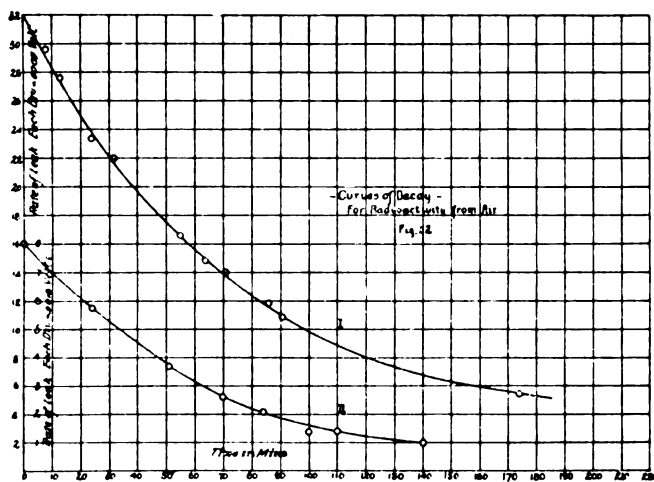
The rate of decay of excited radioactivity was found to be independent of the material of the wire or rod, and, over the range investigated, not much affected by the voltage and time of exposure of the wire. The amount of excited radioactivity on a given wire increases at first regularly with the time, but after several hours' exposure, much more slowly.

In Fig. 2 curves are given showing the rate of diminution of radiating power with time. The ordinates represent divisions of electrometer scale passed over per second. Curve I shows rate of decay of a copper wire, diameter .117 cms., length 20 metres, exposed for 2 hours at a P.D. of $-29,000$ volts. For testing the wire was wound on an iron frame, length 121 cms., placed inside a cylinder of iron gauze. The P.D. between cylinders was 50 volts. The natural leak due to spontaneous ionization of air between electrodes was 2.5 divisions per second. Correcting for natural leak, it will

be seen that ionization current (which is a measure of the intensity of the radiation) falls to half its value in 52 minutes.

Curve II is for a lead wire, length 10 metres, diameter, .125 cms., exposed 190 minutes to $-30,000$ volts. The wire was wound in the form of a flat helix and the ionization current produced was tested between two parallel plates.

The natural leak of apparatus in this case was .14 divisions per second. In this case, the excited radioactivity falls to half its value in about 45 minutes.



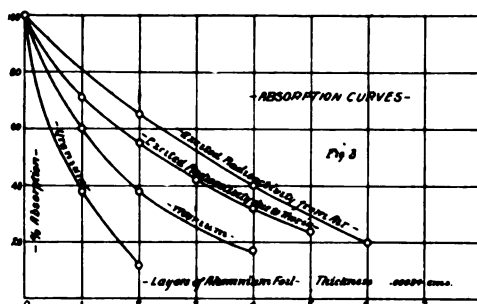
These two observations were separated from each other by an interval of two months and were made under very different atmospheric conditions.

The rate of decay of excited radioactivity due to air is much faster than that produced by thorium, which falls to half its value in 11 hours. No definite comparison can be made with excited radioactivity due to radium, as its rate of decay is irregular and depends upon the specimen of radium employed.

Penetrating power of excited radiation.

Previous experiments had shown that the penetrating power of the excited radiations from thorium and radium were the same. It was of interest to compare the excited radiation due to air with that given out by the radioactive substances.

Lead wire was employed in these experiments as it could readily be retained in the form of a flat helix. The wire was excited by exposure of 2 to 3 hours at — 30,000 volts. It was then wound to form a flat helix and placed between a parallel plate apparatus. The ionization current between plates was observed for different numbers of sheets of thin aluminum foil placed over it.



The results are shown in Curve I, Fig. 3, where the penetrating power of other known types of radiation are added for comparison.

The excited radiation due to air has greater penetrating power than any of the types of radiations which are not deviated by a magnetic field, from the radioactive substances, uranium, thorium, potassium and radium, and also more penetrating than excited radiation produced by radium and thorium.

Experiments are now in progress to determine the variation of the number of ions per c.c. in the air at different times. For this purpose, the air outside the building is drawn through a metal cylinder, 30 cms. in diameter, by means of a fan. The air in its path passes through two insulated parallel wire gauges, 2 cms. apart. The gauge near the open end is connected to the electrometer and the other to a large battery.

For a definite current of air, the current, observed by the electrometer, increases with the voltage until a point is reached beyond which an increase of voltage does not appreciably increase the current. If the second gauge is charged positive, the positive ions travel up against the current of air. When the velocity of the ion in the electric field is slightly greater than the velocity of the current of air, all the positive ions reach the first gauge and electrometer current is a maximum.

From observations of this kind with a current of air varying in velocity between 100 and 250 cms. per second, the velocity of the positive ion has been found to be about 1.5 cms. per second for a potential gradient of 1 volt per cm. This is not very different from the velocity of the positive ion produced by Röntgen rays in air. Sufficient observations have not yet been made to determine velocity of negative ion.

By noting the maximum rate of leak between gauges for a given current of air, the number of positive and negative ions per c.c. present in the air, which is drawn through, can be deduced.

McGill University, Montreal.

Dec. 20, 1901.

A SUSPECTED CASE OF THE ELECTRICAL RESONANCE OF MINUTE METAL PARTICLES FOR LIGHT- WAVES. A NEW TYPE OF ABSORPTION.¹

R. W. WOOD.

(Abstract.)

Small pieces of sodium, lithium, or potassium heated in exhausted glass bulbs deposit on the cold wall of the bulb in the form of a film which shows colors by transmitted light as strong as those produced by the aniline dyes. The color does not seem to depend on the thickness, and all attempts to explain it by the well known principles of interference have been without success. The microscope shows that the deposit is made up of exceedingly minute grains, which are but just barely visible under a $\frac{1}{12}$ inch oil immersion objective. Their diameter is not far from .0002 mm. The colors vanish on the admission of the smallest trace of air. They change in a most remarkable manner if the outside of the bulb be touched with a small piece of ice, or if the glass be locally heated. The change of color produced by the application of ice to the outside of the bulb is always in the direction corresponding to a drift of the absorption band towards the red end of the spectrum. A purple film which has an absorption band in the yellow becomes blue-green when cooled,

¹Presented at the meeting held on Dec. 27, 1901.

the absorption band moving into the red. The cause has been found to be a condensation of the traces of volatile hydrocarbons (derived from the metal) on the colored film, thus immersing the particles in a fluid of high dielectric constant, the effect of which would be to increase the capacity of the system, lower the period of vibration, and move the region of absorption towards the red end of the spectrum. This was proven by forming the film in one-half of a double bulb and immersing the other half in solid CO_2 and ether, thus bringing down all the hydrocarbon vapor. The colored film was found to be no longer sensitive to the local application of ice. It became sensitive, however, as soon as the lower bulb was removed from the freezing mixture and warmed.

Sometimes the film becomes nearly colorless when cooled, the absorption band moving out of the visible spectrum entirely. Films originally pale apple green become deep violet when cooled, the color being as deep as that of dense cobalt glass.

Various experiments have been tried with polarized light at different angles of incidence.

Paper will appear in full in the Proceedings of the London Physical Society and the *Philosophical Magazine*.

FURTHER EXPERIMENTS ON ELECTROSTRICTION.¹

J. S. SHEARER.

(Abstract.)

The experiments of Kortweg and Julius showed that the expansion of hard rubber when placed in an electrostatic field was much greater than in case of glass. In order to test this a set of tubes about one meter long were secured. Smooth layers of tin foil were placed inside and outside these tubes and they were mounted as described in the previous work on glass tubes. Tests were made both with a small Wimshurst and the dynamo-static machine.

In each case a marked expansion was observed which increased steadily while the machine was in action. The return was gradual and suggested thermal expansion as the probable explanation of the

¹ Presented at the meeting held on Dec. 27, 1901.

effect. To test this a coil of flat, thin copper ribbon was wound around the tube and a thin layer of shellac was applied before wrapping with tin foil.

A distinct increase of resistance was observed nearly proportional to the expansion of the tube. The expansion computed from the observed rise in temperature and the known coefficient of expansion for hard rubber was of the same order as that observed.

VISCOSITY OF LIQUIDS DETERMINED EXPERIMENTALLY BY MEANS OF RIPPLE WAVES.¹

BY FLOYD R. WATSON.

(Abstract.)

The method about to be described for obtaining a measure of viscosity grew out of an experiment previously performed by the writer in determining surface tension of liquids.² In this experiment, capillary ripple waves were generated on a plane liquid surface. These waves, apparently because of viscosity, were observed to decrease in amplitude as they progressed, and the thought naturally arose that this decay of motion might afford a means of measuring the viscosity of the liquid.

In accordance with this thought a provisional formula was deduced as suitable for the conditions of the experiment.

$$\mu = \frac{n \rho \lambda^2}{8 \pi^2 \cdot 43429} \cdot \log \left(\frac{r_2 \sqrt{x_1}}{r_1 \sqrt{x_2}} \right)$$

where μ is the coefficient of viscosity.

n the wave frequency.

λ the wave length.

ρ the density of the liquid.

r the radius of curvature of the wave observed.

x The distance of this wave from the origin of wave disturbance.

¹ Presented at the meeting held on Dec. 27, 1902.

² *Physical Review*, May, 1901.

The method of obtaining measurements of these quantities is described in the paper previously cited.

Viscosities have been determined for three liquids as shown in the accompanying table :

<i>Liquid.</i>	<i>Temp.</i>	λ (<i>cm.</i>)	<i>Viscosity.</i>
Tap water	10.5° C.	.395	.0121
" "	10.3	.3925	.0117
" "	9.4	.3924	.0124
" "	9.3	.3922	.0122
" "	9	.3900	.0115
" "	9	.391	.0109
" "	8.5	.389	.0102
Mercury	20	.2875	.0628
"	20	.2813	.0684
"	20	.2875	.0624
"	20	.2878	.0577
"	19.7°	.2888	.0702
"	19.7°	.2888	.0629
Turpentine	21.5°	.2947	.0101
"	20.7	.2936	.0102
"	20.7	.2963	.0106

The results obtained by other workers are quoted here for comparison :

<i>Liquid.</i>	<i>Temp.</i>	<i>Viscosity.</i>	<i>Observer.</i>
Water	17° C.	.011858	Helmholtz ¹
"	"	.01112	Meyer ²
"	"	.01089	Poiseuille ¹
"	"	.01106	Grotian ³
"	"	.01105	König ⁴
"	20	.0102	Drew ⁵
Mercury	17°	.01865	Warburg ⁶
"	10°	.01633	Koch ⁷

It is to be noticed that the values for water viscosity agree substantially with the determinations of other workers ; but that those

¹Wien. Sitzungsber, 50, 107, 1860.

²Pogg. Ann. 113, 85, 1861.

³Pogg. Ann. 157, 130, 1876.

⁴Wied. Ann. 32, 193, 1887.

⁵Phys. Review, 12, 114, 1901.

⁶Pogg. Ann. 140, 367, 1870.

⁷Wied. Ann. vol. 14, 1881.

for mercury are different. The causes of the disagreement are not yet clear to the writer. A comparison of the methods employed reveals the sources of discrepancy. In the calculation of viscosities by other experimenters the question of a possible friction between the liquid and the containing vessel has to be considered, as well as friction between molecules of the liquid. In the method used by the writer this difficulty is not present. On the other hand, in the method of Ripple Waves there is a possibility that surface conditions make the surface viscosity different from that in the interior of the liquid.

Further investigation is contemplated both in theory and experiment.

*Cornell University,
December, 1901.*

MAGNETIZATION OF STEEL AT LIQUID AIR TEMPERATURES.¹

C. C. TROWBRIDGE.

(Abstract.)

The magnetic moments of steel bars obtained by magnetization at -185° C. were compared with the magnetic moments of bars of steel obtained by magnetization at 20° C.

The initial change of magnetic strength produced by heating a bar magnet to 20° C. which had been magnetized at -185° C. was also determined, and compared with the initial change produced by cooling a magnet of the same steel to -185° C. which had been magnetized at 20° C.

Magnets made from Crescent Co. and Sheffield magnet steels were tested.

The magnetic moment of bars magnetized at -185° C. and at 20° C. were found to be approximately the same, other conditions being equal. This was found to be true for both the steels mentioned.

Three Crescent Carbon steel bars magnetized at -185° C. were

¹ Presented at the meeting held on Dec. 27, 1901.

found to lose 37.8, 30.6 and 30.3, per cent. of magnetism when warmed to 20° C. A bar of this steel magnetized at 20° C. lost 9.1 per cent. of magnetism when cooled to -185° C.

These magnets after 9 days of approximately constant temperature at 20° C. showed a total loss, since magnetization, of 39.8, 32.1, 34.6 and 18.6 per cent. of magnetism respectively.

Three bars of Sheffield tungsten steel magnetized at -185° C. lost 15.5, 15.7 and 11.3 per cent. of magnetism when warmed to 20° C. (result 11.3 uncertain).

One bar of this steel magnetized at 20° C. lost 6.1 per cent. when cooled to -185° C.

A bundle of wires (not pure iron) magnetized at -185° C. lost 39.4 per cent. of its residual magnetism when warmed to 20° C.

Bars of tungsten steel were magnetized at -185° C. in a strong field for 1 sec., 6 sec., and 60 sec.; giving magnetic moments 136, 145 and 145 respectively, showing that the magnets tested became approximately saturated at -185° C. in one second.

A bar of the same steel magnetized at 20° C. was found to have 145 as the magnetic moment.

In the last experiments with tungsten steel the determinations were relative only. They were made with a magnetometer of special design which was suggested by Professor Rood and constructed by the writer.

The essential part of the instrument is the suspension system, which consists of two groups of small magnets, set 23 cm. apart, rigidly connected by a fine glass rod. The system is suspended by a single raw silk fibre 10 cm. long. By making the polarity of the two groups of magnets opposite, a system that is approximately astatic is obtained.

The object of the arrangement employed is partly to annul the effects of distant magnetic disturbing influences, such as those that arise from trolley car motors, etc., and partly to obtain a sensitive system that will act on the differential principle.

A magnet placed within a meter of the instrument and outside of the neutral plane between the two groups of magnets acts strongly on the nearest group, producing a deflection of the system.

The instrument was called "A Differential Astatic Magnetometer."

Conclusions drawn from these experiments are as follows :

(1) That approximately the same magnetic moment is obtained whether a bar of tungsten steel or carbon steel is magnetized at normal or at liquid air temperature, other conditions being the same.

(2) That the initial loss in the magnetic moment of a bar of steel magnetized at -185° C. and then heated to 20° C. is much greater than when the bar is magnetized at 20° C. and then cooled to -185° C. A considerable loss occurring in both cases.

(3) That there is a certain amount of unstable magnetism in a newly made magnet, which tends to pass off at the first change of temperature in either direction from that at which magnetization takes place, much more of the unstable magnetism passing off by heating than by cooling.

It was determined that the tungsten steel magnets, while nearly the same length, but only about one-fifth of the mass of the carbon steel magnets gave a higher magnetic moment, than the carbon steel, and that the initial losses of magnetic strength due to changes of temperature of 205 degrees were much less in the case of tungsten steel magnets than for the carbon steel magnets.

It is evident that there is less of the unstable magnetism referred to above in the magnets made of tungsten steel than for those made of carbon steel.

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THE PFAUNDLER CALORIMETER.¹

W. F. MAGIE.

(Abstract.)

The Pfaundler calorimeter consists essentially of two similar cups, one containing a standard liquid and the other the liquid to be tested, which are supplied with equal quantities of heat by an electric current in equal resistances. It is of special value when the liquids to be compared have nearly the same specific heats, because then by a suitable choice of the quantities of the two liquids the rise of temperature can be made nearly the same in both. In this case the princi-

¹ Presented at the meeting held on Dec. 27, 1901.

pal corrections, those for radiation and for the calorimeter constant, depend on the difference of temperature rise, and may in most cases be neglected altogether. In any case that occurs in practice these corrections do not need to be determined with any degree of accuracy. These advantages of the method have been utilized by Stroud & Gee.

The calorimeter cups, as I have constructed them, are of silver ; 6 in. high and 4 in. in diameter. They are fitted with brass covers, as I found that the irregular loss of heat by unequal evaporation, when the cups were left open, as in my (published) form of the instrument, introduced a source of considerable error.

I may say that I have not found that this very important source of error has been given any attention in calorimetric work. It is roughly included in the observations which are made to correct for radiation, but is neglected in the Rumford method.

A full description of the instrument, with examples of the results which can be obtained with it, will be published in the *Physical Review*.

In considering sources of error it may be said that the resistances can be made so nearly equal that their difference is negligible. The same may be said of the two vessels and their appurtenances, barring the thermometers, which may differ enough in the quantity of mercury in the bulb to make a trifling difference in the calorimeter constants.

The evaporation is not stopped by the use of the covers. They become covered with a deposit of dew, but at least the evaporation is restrained and rendered more uniform.

The most troublesome errors arise from failures of various sorts in the stirring. I detected differences due to the unequal rate of rotation of the paddles, corrected by care in making the pulleys ; to unlike slope of the blades of the paddles, corrected by making the paddles geometrically similar and by rotating half the time in one sense and half the time in the other ; to insufficient mixing when I stirred too languidly, corrected by brisker stirring ; though there is no final test here as to what is a sufficient stirring ; and to occasional contact of the paddles with the walls of the cups ; the blades must be as long as possible so as to get at the dead water in the corners near the bottom, and any little tilt of the cover makes contact with the walls

possible. An occasional scrape of one paddle will raise the temperature of the cup in which it occurs perceptibly faster than it ought to rise. Fortunately the scraping can generally be detected by the ear; but if it occurs during an observation, the result obtained is worthless.

The gain or loss of heat by radiation is generally the same in each cup—if the amounts of liquid in each are properly chosen—as may be shown by the concordance of the rate of rise or fall of the two thermometers. If the amounts of liquid are very different—as they are when the calorimeter constant is to be determined—the radiation has to be examined and allowed for.

ON MAGNETOSTRICTION IN BISMUTH.¹

A. P. WILLS.

(Abstract.)

Bidwell, in a paper in the Philosophical Transactions for 1888, states that he found an apparent extension in a bismuth rod 13.2 cms. in length under a longitudinal magnetizing force of less than 1,000 C. G. S. units, produced by a solenoid. The extension under a force of 842 C. G. S. units is given as 1.5 ten millionths of the length; and the extension when the experiments were discontinued was increasing *very* much more rapidly than the field.

Since with a bismuth rod, the effect of the ends is negligible it was thought desirable, in the present experiments, to study the behaviour of bismuth under higher magnetising forces produced by an electromagnet. A cylinder of bismuth, 1 cm. long and .5 cm. in diameter, was placed between the pole pieces of an electromagnet with its axis along the lines of force. A system of levers with a high power microscope was used as a multiplying device. One head division of the micrometer eye-piece on the microscope would correspond to an extension (or contraction) in the bismuth cylinder of 1.31×10^{-8} cms. The multiplying power of the

¹ Presented at the meeting held on Feb. 22, 1902.

lever system was checked satisfactorily by experiments on the bending of a steel spring under small weights.

With a field of 3,200 C. G. S. units no effect could be detected which could not be ascribed to one of the following causes :—(1) heat from the magnet coils ; in which case time was required to produce the effect ; (2) the action of the magnet, on closing or making its circuit, upon the induced currents in the levers themselves. In this case a sudden jerk was observed, the pointer then returning to zero.

It is intended to continue the experiments with a more powerful magnet.

VARIATION OF CONTACT RESISTANCE WITH CHANGE OF ELECTROMOTIVE-FORCE.¹

H. C. PARKER.

(Abstract.)

Measurements of the resistances just described were made with the following voltages : 14, 70, 140. It was found in every case that the resistance decreased with increase of electromotive-force.

This decrease may be only a few per cent. or the resistance may be reduced to a small fraction of the original value.

Improving the contacts renders this change in resistance much less marked.

The decrease of resistance with increase of electromotive-force may be caused by a kind of coherer action taking place at the contacts.

Very high resistances, measured by the electrometer method, are found to practically obey Ohm's law. This is explained by the fact that the contact resistance is probably a very small portion of the entire resistance.

In order to express these very high insulating values in ohms it was necessary to find some form of standard that, while great enough to be measured by the electrometer method, was not beyond the limits of the direct deflection method. The form of standard finally

¹ Presented at the meeting held on Dec. 27, 1901.

adopted consisted of black oxide of manganese on Cobalt glass. This material was found to be perfectly suited to the construction of standards of high resistance, giving a range of adjustment from about 1 meg ohm up to 10,000 meg-ohms if required.

The experiments were to determine the best protective covering to be employed and the effect of time on the several different forms of standards. A mixture of resin, with about 5% or 10% of yellow wax, was found to be very satisfactory, while for standards of even several hundred meg-ohms no insulating covering is necessary. Paraffin or wax produce such a great increase in resistance with time, that they should not be employed in any case.

These standards, when well made, after a month's ageing may remain nearly constant for several weeks at a time. The effect of the summer months was to greatly increase these resistances. This may result from the considerable changes in temperature which are likely to occur in the laboratory during that time and the consequent expansion and contraction produced in the standards.

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PUBLISHED QUARTERLY

BOARD OF EDITORS

J. S. AMES

M. I. PUPIN

ERNEST MERRITT

IX.

JUNE, 1902

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PUBLISHED BY

THE AMERICAN PHYSICAL SOCIETY

1902

American Physical Society.

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J. S. AMES, M. I. PUPIN, ERNEST MERRITT.

AMERICAN PHYSICAL SOCIETY.

CONSTITUTION.

ARTICLE I.

This Society shall be called the American Physical Society.

ARTICLE II.

The object of the Society shall be to promote the advancement and diffusion of the knowledge of physics.

ARTICLE III.

The officers of the Society shall be a President, a Vice-President, a Secretary, and a Treasurer.

ARTICLE IV.

The officers of the Society, together with eight other members, shall constitute a Council, which shall have general charge of the affairs of the Society.

ARTICLE V.

1. The officers of the Society and other members of the Council shall be elected by ballot at the Annual Meeting of each year. An official ballot shall be sent to each member at least one month prior to the Annual Meeting, and such ballots, if returned to the Secretary in envelopes bearing the names of the voters, shall be counted at the Annual Meeting. Each such ballot shall contain a name proposed by the Council for each vacancy, with blank spaces in which the voter may substitute other names. A majority of all votes cast in person or by mail shall be necessary to election. In case of failure to secure a majority for any office, the members present at the Annual Meeting shall choose by ballot between the two having the highest number of votes. The term of office shall be one year for officers and four years for other members of the Council, and until their successors shall be elected. No member shall be elected as President more than two years in succession. No elected member of the Council, having completed a term of four years, shall be re-elected until at least one year shall have intervened.

2. If an office for any reason becomes vacant, it shall be filled by the Council. If any elected member of the Council die or resign more than one year before the expiration of his term, the vacancy for the unexpired term shall be filled by the Society at the next Annual Meeting.

ARTICLE VI.

This Constitution shall not be amended unless notice of the proposed amendment be sent by mail to every member of the Society at least four weeks in advance of the meeting at which such amendment is to be considered ; and such amendment in order to be adopted must receive two-thirds of the votes cast in person and by mail.

BY-LAWS.

I.

For the election of a new member to the Society it shall be necessary that a proposition in due form signed by two members of the Society shall be presented at a meeting of the Council, and that at a subsequent meeting of the Council the person named in such proposition shall receive the favorable ballots of a majority of the members present.

II.

The annual dues shall be five dollars payable on the 1st of January. Each new member, if elected before July 1, shall pay the full dues for the year; if elected after July 1, he shall pay two dollars and a half for the half year. Should the annual dues of any member remain unpaid beyond a reasonable time, the Council shall remove his name from the list of members, after due notice.

III.

On the payment of fifty dollars in one sum, any member may become a life member and shall thereafter be exempt from all annual dues.

IV.

Four regular meetings shall be held each year, at such times and places as shall be ordered by the Council. The meetings shall ordinarily be held in New York. One of these, to be called the Annual Meeting, shall be held on such day as the Council may decide upon between the 26th and the 31st of December inclusive.

V.

Notice of the time and place of each meeting shall be sent by the Secretary to such members of the Society as may request it.

VI.

The order of business at the meetings of the Society shall be as follows :

1. Reading of the minutes.
2. Recommendations and reports.
3. Elections.
4. Miscellaneous business.
5. Presentation and discussion of papers previously announced.
6. Any other scientific communications.

VII.

No question relative to administration shall be considered at any meeting except the Annual Meeting, without the recommendation of the Council.

VIII.

1. The President shall convoke the Council whenever the affairs of the Society require it.

2. A request in writing from two members of the Council shall render the convocation obligatory.

IX.

1. The Society shall issue an occasional publication to be called the **BULLETIN OF THE AMERICAN PHYSICAL SOCIETY**. It shall contain reports of the meetings, with such notices of the papers read or presented as may be sufficient to indicate their nature and contents.

2. The publication of this **BULLETIN** shall be the duty of the Council, which may appoint not more than three of its members to serve as a Board of Editors.

X.

It shall be the duty of each President to deliver an address before the Society at the Annual Meeting next succeeding his first election as President of the Society.

XI.

Whenever it shall appear to the Council that a sufficient number of members of the Society are desirous of conducting in any locality periodic meetings for the reading and discussion of physical papers, the Council may authorize the formation of a Section to be composed at each sectional meeting of such members of the Society as may be present ; and the Council shall have the right to withdraw such authorization.

XII.

Papers intended for presentation at any meeting or sectional meeting of the Society shall be passed upon in advance of the meeting by a program committee appointed by or under the authority of the Council ; and only such papers shall be presented as shall have been approved by such committee. Papers in form unsuitable for publication, if accepted for presentation, shall be referred to on the program as preliminary communications or reports.

XIII.

No by-law shall be enacted, amended or suspended, except by a two-thirds vote of the members present at a meeting of the Society, and upon the recommendation of the Council.

MEMBERS.

(JUNE 15, 1902.)

- ABBE, CLEVELAND, Professor of Meteorology, U. S. Weather Bureau, Washington, D. C.
- AMES, JOSEPH S., Professor of Physics, Director of the Physical Laboratory, Johns Hopkins University, Baltimore, Md.
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MEMBERS.

7

- BRYANT, ERNEST C., Professor of Physics and Mathematics, Middlebury College, Middlebury, Vt.
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- HALL, GEORGE E., Director of the Yerkes Observatory, Williams Bay, Wis.
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